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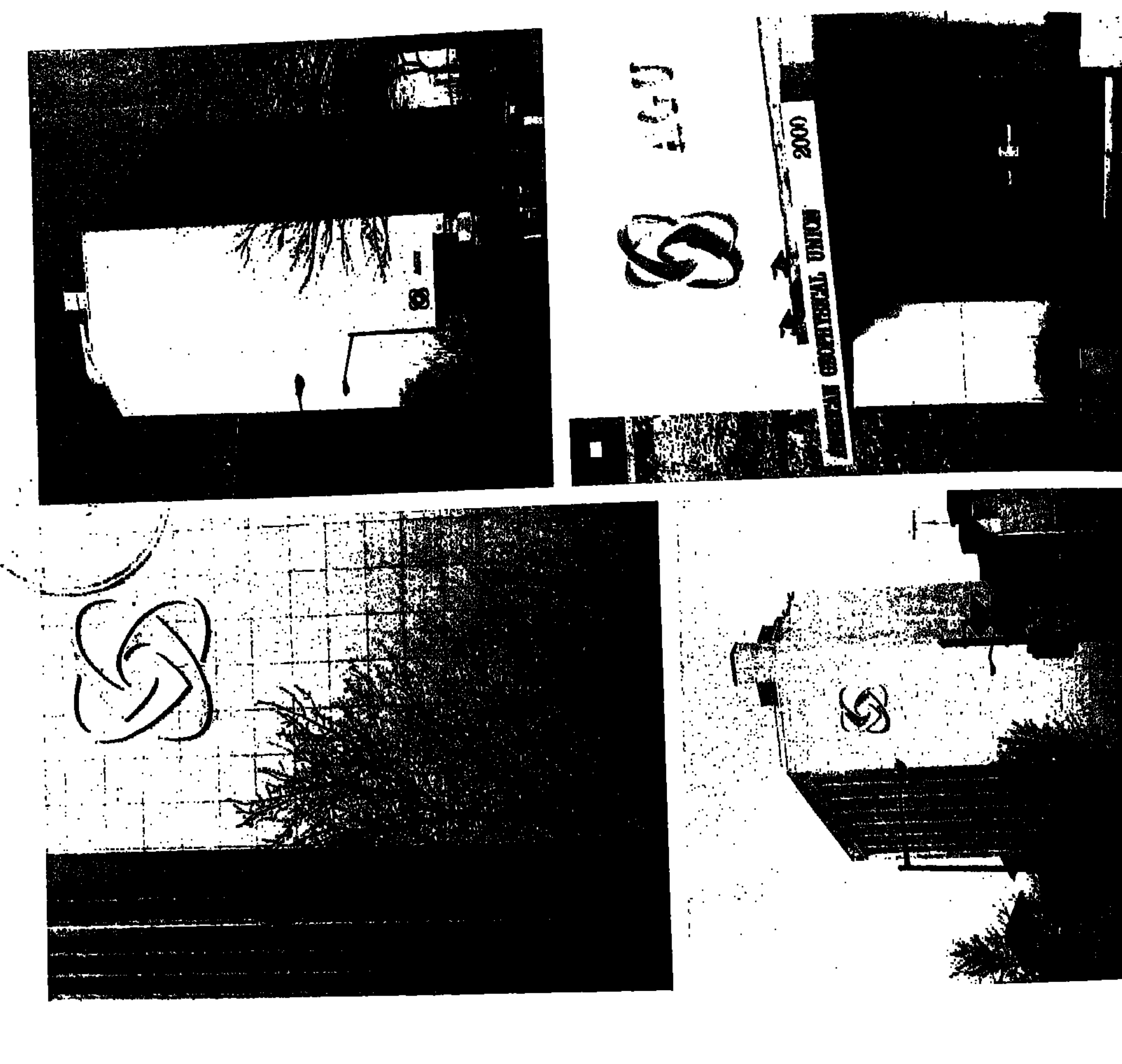

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Tectonophysics

Volcanology

A New Interdisciplinary Focus on Precipitation Research

Committee on Precipitation, AGU Hydrology Section

Introduction

In the Hydrology Section of the American Geophysical Union, a new Committee on Precipitation was formed in fall 1982 consisting of nine members from the fields of hydrology, atmospheric sciences, statistics, and mathematics. The objective in bringing together these scientists from different disciplines was to collectively address important problems and directions in precipitation research that are of central interest to the long-range development of hydrologic science. It is somewhat trite but true that advances in the stochastic modeling of rainfall require corresponding advances in the understanding of the physical processes which produce precipitation. Consequently, a working dialogue between hydrologists and atmospheric physicists in formulating and addressing research plans seems quite appropriate. In this same spirit, advances in the stochastic modeling of rainfall require advances in mathematical and statistical techniques. Issues pertinent to major unsolved problems and research directions in understanding, modeling, and predicting of precipitation in space and time were extensively discussed among the committee members and are summarized in this article.

Hydrologic science deals with water in all of its forms: in the atmosphere, in lakes, in oceans, in streams, and underground. However, either directly or indirectly, precipitation is the source of many varied effects. For example, streamflows, infiltration into soils, and groundwater recharge and evaporation are all directly related to the precipitation patterns peculiar to a region. Hydrologic studies are concerned with predictions on time scales ranging from a few days to a few weeks, months, seasons, years, or even from several decades to a few centuries. The spatial scales of central interest in hydrology are normally dictated by the dimensions of river basins, which can range from a few to several thousand square kilometers. On these space-time scales, precipitation exhibits significant variability. To model this variability, hydrologists and meteorologists have traditionally employed somewhat ad hoc probabilistic and statistical techniques. Moreover, these techniques have been developed primarily for modeling temporal fluctuations in precipitation at fixed points in space such as at a rain gauge [see, e.g., *Waymire and Gupta*, 1981; *Katz*, 1983]. Owing to the diversity of climatic processes in different geographic regions and to the lack of detailed understanding of the physical processes producing rainfall on the scales of hydrologic interest, probabilistic and statistical modeling have been largely confined to a case by case analysis without a basis in the physics of precipitation and the observed structure of precipitation systems.

In this article we discuss three broad issues related to future research on precipitation. First, because physical/dynamical processes interact on different scales, it seems impossible within the foreseeable state of the art to formulate a single model that includes all of the processes operating at these scales. Thus, a major problem in modeling precipitation is appropriately linking the stochastic descriptions at the unresolved scales with the deterministic physical/dynamical descriptions at the resolved scales. The "unresolved scale" refers to scales in which the fluctuations about the average values of certain parameters and physical variables are significant enough to require description in some form. Second, although physical/dynamical considerations are expected to play an important role in advances in stochastic modeling of precipitation, the problems of parameter estimation and statistical inference are not expected to be solved by appealing only to precipitation physics. Moreover, new statistical techniques remain to be developed for the class of stochastic models likely to emerge in this area, particularly for stochastic descriptions of space-time rainfall. Third, the issues concerning measurement of precipitation using rain gauges, radar, and satellite need much research in relation to precipitation modeling and inference problems. In the opinion of this committee, significant advances in precipitation research will require the concerted and combined efforts of scientists from a variety of disciplines. Some recommendations will be made regarding ways to reach this objective.

Spatial/Temporal Scales

Precipitation is one of the most difficult meteorological quantities to forecast because it is the product of a complex combination of dynamic, thermodynamic, and cloud microphysical processes. An important emphasis in meteorology has been placed on the identification of meteorological phenomena, including precipitation patterns, in terms of the interactions of physical processes operating on a variety of scales in time and space. Several different systems of terminologies have been used to describe these scales; *Orlanski*'s [1975] terminology has been most widely adopted and is used in this article.

Because the scales of the physical/dynamical processes that produce and distribute precipitation constitute a scale continuum, for both theoretical and practical reasons a model describing or predicting precipitation can have only limited temporal and spatial resolution. Atmospheric processes at the unresolved scales have to be treated statistically because the information needed to describe these processes is not available or because the physical processes themselves lead to inherent fluctuations at such scales. In this latter case, owing to the nonlinear and turbulent nature of atmospheric flow, even processes resolved by a model have only limited ranges of predictability in the deterministic sense. Beyond the limits of predictability, only statistical treatment of the processes is possible. A major task in precipitation modeling is to determine the statistical structure of the unresolvedprocesses and to couple this statistical structure to the physics/dynamics of the processes at the resolved scales.

The hypothesis that the statistical fluctuations at smaller unresolved scales are linked with the dynamics at larger resolved scales appears physically tenable because of the strong control and feedback mechanisms at different scales among the processes producing and distributing precipitation. Observations also appear to support this hypothesis. For example, studies of meso-β scale (20–200 km precipitation features over the tropical Atlantic have shown that their behavior is modulated by large-scale air motions in the form of macro-β (2,000–10,000 km) or synoptic scale waves in the middle troposphere [see *Houze and Betts*, 1981]. These precipitation systems usually occur in a preferred region of the large-scale waves (in and ahead of the wave trough). Such large-scale dynamical control over the behavior of smaller scale precipitation patterns holds not only in the tropics but also in the middle latitudes [*Houze and Hobbs*, 1982]. This deterministic aspect of the occurrence of precipitation at the macro-β scale is accompanied by an uncertainty in the exact position in the occurrence of smaller-scale precipitation patterns within a large meso-α scale (200–2,000 km) area. This uncertainty in the occurrence, intensity, variability, and duration in space and time of the precipitation patterns makes a crucial difference in responses of hydrologic basins to precipitation.

Stochastic-Dynamic Modeling

A major discovery of the last 10 years has been the recognition of the importance of organization of precipitation patterns at the meso-β scale. In an unstable environment, cumulonimbus clouds at the meso-γ scale (2–20 km) are often organized into characteristic meso-β scale precipitation patterns. The internal structure of these precipitation patterns includes a leading edge of intense convective cells, about 25 km in width and 200 km in length. This leading edge is frequently arc-shaped. Rainfall rates in this portion of the precipitation pattern are highly variable (10–100 mm hour^{-1}). Behind the leading edge lies a stratiform precipitation region in which a meso-β scale area of rainfall is characterized by rather steady, light to moderate precipitation rates (1–10 mm hour^{-1}).

In a stable environment, band-shaped areas of moderate to heavy precipitation at the meso-β scale, called rainbands, are often embedded in a large area of stratiform clouds at the meso-α or macro-β scale. These rainbands are typically 5–50 km in width and 100–200 km in length. The dynamical and microphysical processes involved in the formation of rainbands are not yet understood. A more detailed description of the precipitation and cloud structures at the various scales can be found in the review papers by *Houze* [1981] and *Houze and Hobbs* [1982].

The organization of the precipitation fields at the meso-β scale described above can be qualitatively incorporated into stochastic representations of the ground level rainfall intensity fields. These representations can then be exploited for investigating various statistical features of these fields (e.g., covariances, extremes, and crossing properties). Even though this line of research was initiated by *LeCam* [1961] more than 2 decades ago, little progress was made in this direction, partly because of mathematical difficulties encountered in obtaining analytical results. Some recent findings, however, call for optimism in the future. For example, *Waymire et al.* [1984] have demonstrated that a stochastic representation of a precipitation field which takes into account the observed organization in extratropical cyclonic storms at the meso-β scale admits a spectral representation which satisfies Taylor's hypothesis concerning fluid turbulence for time intervals smaller than the mean life time of convective rainfall cells embedded inside a rainband. Beyond this time interval, Taylor's hypothesis is no longer valid. These features were observed and reported a decade ago by *Zawadzki* [1973].

The stochastic models of precipitation intensity fields being explored in hydrology suggest certain natural mathematical problems. These models are typically point random field models (see *Waymire et al.* [1984], for example). For such representations the calculation of exact probabilities in explicit form is difficult, if not impossible. Also from a physical viewpoint, the interest generally lies in describing the evolution of certain averages of the rainfall intensity field at suitably chosen scales rather than the evolution of the rainfall intensity field itself. As a solution to this problem, one is naturally led to the problem of obtaining asymptotic estimates which would apply to evolution of rainfall averages in space and time. This scheme of research is in the same spirit as, for example, the use of the central limit theorem to obtain asymptotic estimates for probabilities associated with sums of random variables when the calculation of exact probabilities is all but impossible and physically the objective is to study the evolution of "space-time averages" [see, e.g., *Wax*, 1954]. The asymptotic investigations in the context of precipitation fields would also require that careful attention be given to scales in both space and time as well as to statistical dependencies so that links between statistical/dynamical descriptions at different scales may be properly understood. The links between different scales are also the ingredients of the problems confronting atmospheric scientists. For example, recently it has been suggested that cloud and precipitation fields constitute a turbulence continuum at spatial scales ranging from 1 km to 10^3 km in horizontal extent [see, e.g., *Lovejoy*, 1982]. Using satellite and radar data, these investigators reported a power law relationship for the cloud and precipitation pattern perimeters and areas which seem to hold over these spatial scales, thereby suggesting the existence of a continuous turbulence field changing from a three-dimensional structure at small scales to a two-dimensional structure at the large scales. If such a continuous structure indeed exists it would impose a global constraint on the point random field models of precipitation fields being explored in hydrology [see, e.g., *Waymire et al.*, 1984]. However, the dynamic coupling between processes at different scales seems to be the key to the physical understanding of such a structure.

The stochastic models of space-time rainfall discussed above are developed directly from assumptions about the precipitation fields and exclude the natural evolution of these fields dictated by the laws of physics and dynamics. An important direction for future research in this area would be to understand the dynamic coupling between the meso-β scale fluctuations and the time-averaged dynamical behavior of atmospheric processes at larger scales. Recent research exemplifying this direction addresses the problem of understanding the way in which the thermal gradients in a wide spread stratiform cloud can produce bandlike features near a front [*Leary et al.*, 1983]. Further studies of this type should help provide an enhanced understanding of the role of dynamics in precipitation fluctuations. One of the central problems in modeling the atmosphere has been the statistical treatment of weather elements which produce precipitation. Owing to the release of latent heat of condensation, precipitation producing processes represent an energy source for the atmosphere. A rigorous description of these processes seems essential for the improvement of weather prediction. Some attempts have been made to study the statistical ensemble properties of clouds and their effects on the larger scale weather systems [*Arakawa and Schubert*, 1974; *Cho*, 1978]. These studies have emphasized the dynamic and thermodynamic interactions between processes at different scales and are still in an early stage of development. Further research on control and feedback mechanisms between various scales of precipitation systems, including important boundary effects (e.g., orography, roughness discontinuities, and soil moisture) is clearly needed.

Statistical Inference

Although dynamics is expected to play an important role in the stochastic modeling of precipitation, it is unreasonable to expect that it will be possible to specify all the parameters in stochastic models solely from dynamics. Therefore, the status of parameter estimation and hypothesis testing procedures for stochastic rainfall models becomes a critical problem. Past trends show that model development has outpaced the development of inference procedures. This problem is particularly acute for space-time rainfall models. The only classes of space-time models for which satisfactory inference procedures are available are those that can be specified by (simple) spatial and temporal autocovariance functions. Moreover, judging from the current situation concerning inference procedures for the models representing the temporal evolution of rainfall, there is a significant need for rapid improvement in inference procedures for more complex space-time models. However, many procedures applicable to temporal rainfall models are tied to the ordering of the time parameter. This state of affairs seriously limits the common route of developing higher dimensional results as gen-

Article (cont. on p. 380)

The Oceanography Report

The Oceanography Report

The focal point for physical, chemical, geological, and biological oceanographers.

Editor: Arnold L. Gordon, Lamont-Doherty Geological Observatory, Palisades, NY 10964 (telephone 914-359-2900, ext. 325).

Farewell Remarks by Chris Mooers

For 6 years it has been my privilege and pleasure to serve the Ocean Sciences Section as an elected officer. First as Secretary, then as President-Elect, and finally, as President. The tacit theme I have pursued through these years has been to help the Ocean Sciences Community awaken to opportunities within AGU, to "flex its muscles" as a large, strong, rapidly growing segment of AGU, and to become involved in using AGU's programmatic resources for the benefit of the intellectual and professional development of the ocean sciences. (Our section is the second largest of 10 sections and may become the largest within several years, if the present relative rate of growth is sustained.) Like any large organization, AGU has inertia; however, we have learned that it is flexible and yields to and, in fact, supports the initiatives of activist. And we have only scratched the surface.

In recent years, the Ocean Sciences community has continued to grow and mature. Much of its scientific communications has involved reporting results of the first two generations of "large science" programs in AGU (and other) meetings and journals, while not neglecting advances still to be gained by "small science." Major process, especially on the mesoscale, and regional studies have yielded not only major scientific results but also the community expertise and confidence to proceed to higher levels of quantitative science, to larger-scale and longer-term problems, and to multidisciplinary studies. With declining funding levels and aging facilities, the field has become more competitive, just as it is poised to move into what may be its "prime." In this situation, some of us thought it was important to move toward a higher level of cohesiveness, professionalism, and sense of community. One avenue of initiative open to us in community building was a stronger role in the programs of AGU.

Let me summarize some of the initiatives taken. The Oceanography Section was renamed the Ocean Sciences Section to recognize the breadth of our interest and our continuing transition to a quantitative, predictive science. *The Oceanography Report*, edited by Arnold Gordon and issued on a monthly basis in *Eos* has been a great success as a vehicle for community news; it has paved the way in AGU policy circles for an Ocean Sciences Bulletin if and when we are ready for it. Under A. D. Kirwan's, and then Jim O'Brien's, editorial leadership, a component *Journal of Geophysical Research* dedicated to the oceans has been brought into existence. The recently published *Careers in Oceanography* booklet, produced under Charles Hollister's leadership, has given us an exciting, straight-talking recruiting pamphlet for the first time. We now have an Ocean Sciences Education Secretary, Peter Brewer, to answer inquiries from young people. Ocean Sciences luncheons have become fixtures at all national meetings. They are used for building a sense of community through discussion of Section and AGU issues; for presentation of a major, informal talk by a community leader, usually from Washington, as an unofficial exercise in accountability; and for presentation of the recently instituted Ocean Science Awards, given for outstanding and sustained contributions to the community through service, research, leadership, and so forth. A campaign has continued to welcome biological oceanographers at AGU meetings and as AGU members. Part and parcel with this has been the continued series of joint, experimental meetings with ASLO, and now other societies, beginning with San Antonio (convened by Worth Nowlin and Dick Eppley) in February 1982, colocation of ASLO and AGU meetings in December 1982, the Ocean Sciences Meeting 1984 in New Orleans in January (convened by John Apel and Dick Barber), and the upcoming integrated ASLO/Ocean Sciences Section Program (planned by Wolfgang and Pat Kremer) at the December 1984 AGU Meeting. We have now settled on a biennial Ocean Sciences Meeting.

In recent years, our hardworking, creative program chairmen for AGU national meetings have been Clayton Paulson, John Bane, Dave Cutchin, and Bob Molinari. Many others have served on program committees, as session chairmen, on ad hoc committees of the AGU per se. The point to be emphasized is that the Union and the Section are very much participatory entities and that the Ocean Sciences community can be strengthened by even broader participation. Please let the new Ocean Sciences President, Joe Reid, know if you want to be involved and in what capacity.

Part of the AGU-wide effort to update and "standardize" section bylaws is the establishment of an Ocean Sciences Executive Committee, consisting of three elected section officers and up to five others. Under my "reign," besides Joe Reid, Peter Brewer, and me, the members have been Arnold Gordon, Jim O'Brien, John Apel, Harmon Craig, and Jim Baker. This Executive Committee does strategic planning for the Section and effectively extends the leadership. Together with the Geodesy Section and the President of AGU, we have pressed for the issue of a national policy statement on the releasability of GEOSAT data. On a Union-wide basis, the role of the sections in the selection of AGU Fellows has been greatly strengthened. The Ocean Sciences Section now has an ad hoc AGU Fellows Nominating Committee, chaired by the President-Elect. Consequently, we have presented better documented cases and have been much more successful in the election of Ocean Sciences Section members as AGU Fellows. (There is still a need for more members to nominate colleagues.) Last, a new AGU monograph series in coastal and estuarine regimes has been initiated, with the first volumes to appear within a year.

Much more potential remains to be tapped within AGU. For example, the Ocean Sciences Section has not exploited much the topical meetings mechanism for scientific communications. We have not been fully active in all-Union sessions (e.g., Frontiers of Geophysics.) With more participation in organizing scientific meetings, the quality and coherence of our talk and poster sessions can be improved. (We have made improvements there through the aggressive pursuit of better meeting rooms and the organization of predesignated thematic sessions.) More could be done with joint sessions with other sections; such as, Geodesy, Hydrology, and Atmospheric Sciences. AGU can help us in organizing more effective graduate student recruitment efforts. The Ocean Sciences Bulletin idea, modeled after the *Bulletin of the AMS* and *Physics Today*, is waiting for someone to come forward as the inaugural editor. There is also room for more specialty journals. Finally, the possibility exists to organize an Ocean Sciences society within AGU if there is sufficient need, interest, consensus, and leadership.

There are exciting times ahead for the ocean sciences, and the Ocean Sciences Section needs to anticipate them, and to help lead them. For example, owing to the imperatives of the scientific agenda for global ocean circulation, marine ecosystem, biogeochemical research, benthic province, and other studies, of technological opportunities provided by super computers, microprocessors, new sensor systems, future ocean satellites, retrievable and expendable profilers, moored and drifting buoys, and ships-of-opportunity, of scientific opportunities provided by new understanding and models, and of programmatic needs associated with the missions of the new National Ocean Service and the soon-to-be revitalized Naval Oceanography Program, the dawning of global synoptic oceanography is at hand. The community will need help in adjusting to the sociological shock of working in real-time, and the Ocean Sciences Section can help to communicate and foster the "revolution," and the concomitant educational needs and employment opportunities that the new industry of operational oceanography will bring. If oceanographers can commit themselves to work in real-time, benefits from the operational communities will accrue in the form of cooperation and resources to achieve otherwise unobtainable goals in global ocean studies of climate variability and related topics. Other benefits include the ability to conduct up-to-date quality control of data acquisition, adaptive sampling strategies, and onboard scientific analyses. Similarly, the prospective large scale exploration for resource management (exploitation and conservation) of our EEZ will provide new scientific challenges and opportunities in the coastal ocean, as will working with other nations in developing their ocean science capabilities for EEZ resource management. For all of this, oceanographers will need to communicate with other science disciplines, engineers, and technologists. Again, the Ocean Sciences Section (or Society) can serve to help traverse these new frontiers.

Chris Mooers is *outgoing President, AGU Ocean Sciences Section.*

News & Announcements

Physics of Shallow Estuaries and Bays

The objective of the symposium is to promote the exchange of information on recent developments in estuarine physics between physical oceanographers and coastal engineers. Emphasis will be on shallow estuaries and bays (well-mixed and partially mixed) and reef lagoons.

The symposium stresses results of field and laboratory measurements and the formulation of the governing equations and boundary conditions as opposed to numerical techniques. Both well-mixed and partially mixed estuaries are included. The following topics will be covered: (1) large-scale transport processes (mixing); (2) tide and wind-induced residual flow; (3) small-scale turbulence; (4) suspended sediment transport; and (5) exchange between ocean and estuary/bay.

The symposium will be held at the Rosenstiel School of Marine and Atmospheric Science, University of Miami, Florida. The dates of the symposium, August 29, 30, and 31, 1984, were selected to allow participants to combine attendance of the symposium with the 19th International Conference on Coastal Engineering (ICEE) to be held in Houston, Texas, September 3–7, 1984. The symposium is cosponsored by the Coastal Engineering Research Council of the American Society of Civil Engineers and the Rosenstiel School of Marine and Atmospheric Science.

For additional information, registration, etc., write: Physics of Shallow Estuaries and Bays, c/o Division of Ocean Engineering and *Applied Marine Science*, RSMAS, University of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149 (telephone 305-361-4160).

Meetings

New Directions in Internal Wave and Microstructure Research

Collaboration of oceanographers across traditional boundaries always results in exciting new insights into the complex processes which govern oceanic motions. Such collaboration was evident at the second annual 'Aha Huliko'a Hawaiian Winter Workshop, held in Honolulu, Hawaii, January 18–20, 1984. This year's topic was Internal Gravity Waves and Small-Scale Turbulence. Participants from Europe, Canada, and the United States reviewed recent developments and proposed intriguing studies in the kinematics and dynamics of internal waves, fine structure, and microstructure. Here we summarize the highlights of the meeting and identify some of the emerging trends, all subject to the participants' biases.

Internal Waves

Internal waves are viewed as an important link in the overall oceanic energy cascade from the large scales of generation to the small scales of dissipation. Although the dominant sources and sinks for internal waves have not been identified, the following concept is generally accepted: Energy enters the internal wave field at large scales and cascades down to small scales by nonlinear wave-wave interactions. When the shear reaches a critical value, the waves break and generate small-scale turbulence and microstructure. At microscales energy is dissipated by molecular processes. Research that led to this picture has been dominated by the concept of a universal internal wave spectrum, an idea introduced over a decade ago by *Garrett and Munk* [1972]. During the workshop, the concept of a universal spectrum was challenged, whereas the link between internal waves and microstructure was substantiated.

"Universal" Spectrum. Observed spectra usually fit the "universal" spectrum to within a factor of 3 for frequencies significantly above the inertial and less so in the near-inertial band [*Wunsch*, 1976; Briscoe; Levine]. (Note: Undated references refer to talks given at the workshop. These talks will be published in the proceedings. Copies may be obtained from Peter Müller, University of Hawaii, Department of Oceanography, 1000 Pope Road, Honolulu, HI 96822.) This means that there is an order of magnitude variation in the spectral levels. These variations are likely the dynamical signatures of the sources, sinks, and internal transfers of the internal wave field. It is these dynamical features that have become the object of internal wave research.

The deviations of the internal wave field from the universal form exhibit definite patterns. Energy in the near-inertial frequency band varies in response to storms and to mesoscale features (D'Asaro), as well as geographically and with depth [*Fu*, 1981]. The energy in the higher frequency continuum varies seasonally and geographically (Briscoe, Levine, and Figure 1) and near topographic features (Eriksen). Clear patterns exist in the data; explanation of their dynamics is a challenge for future research.

New measurement techniques like Doppler sonars reveal local spectra that are not universal but show an irregular structure with ridges and shoulders (Pinkel and Figure 2). *Nonlinear Interactions.* Nonlinear interactions among internal waves have primarily been analyzed by using the weak resonant interaction approach. Detailed calculations have been made by using this technique, and an inertial range theory has emerged similar to the one in turbulence theory [*McComas and Müller*, 1981]: Nonlinear interactions cascade energy down the spectrum from the generation to the dissipation scale. The level of the energy spectrum adjusts itself to the energy flux through the spectrum. The downscale cascade is associated with an energy transfer from high to low frequencies, somewhat opposite to conventional wisdom. The appropriateness of the weak resonant interaction approach for small-scale waves has been questioned because interaction times are often much shorter than the periods of the waves [*Holloway*, 1980].

Now, nonlinear interactions are investigated by two new methods: numerical integration of the Navier-Stokes equations in two dimensions (Holloway and Figure 3) and Monte-Carlo simulation of the Eikonal equations that describe the evolution of a small-scale wave in a background wave field (Henyey). Their preliminary calculations show unexpected and exciting results: an upward mass flux (mixing) at low wave numbers in Holloway's calculation and preferred layers of breaking "patches" in the Eikonal approach. Unlike the weak interaction calculations, the new approaches produce space-time results that will eventually allow direct comparison with experimental data. Such comparison certainly will stimulate a greater interaction between theoretical and observational oceanographers.

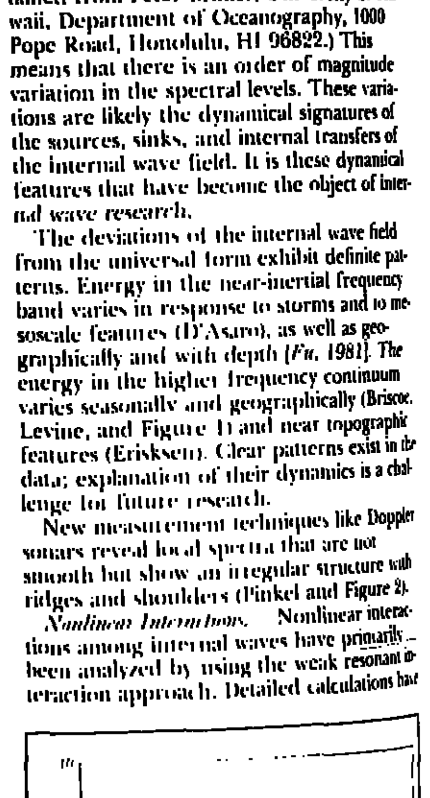

Fig. 1. Seasonal variability of the internal wave continuum. The data points represent the high frequency (0.1–2.0 cph) horizontal kinetic energy from 13 moorings in the North Atlantic over a 10-year period. The moorings are all subsurface. The instrument depths are 114–506 m, and the locations range from 10°–50°N and 12°–71°W. The error bars are plus and minus one standard deviation (courtesy of M. Briscoe).

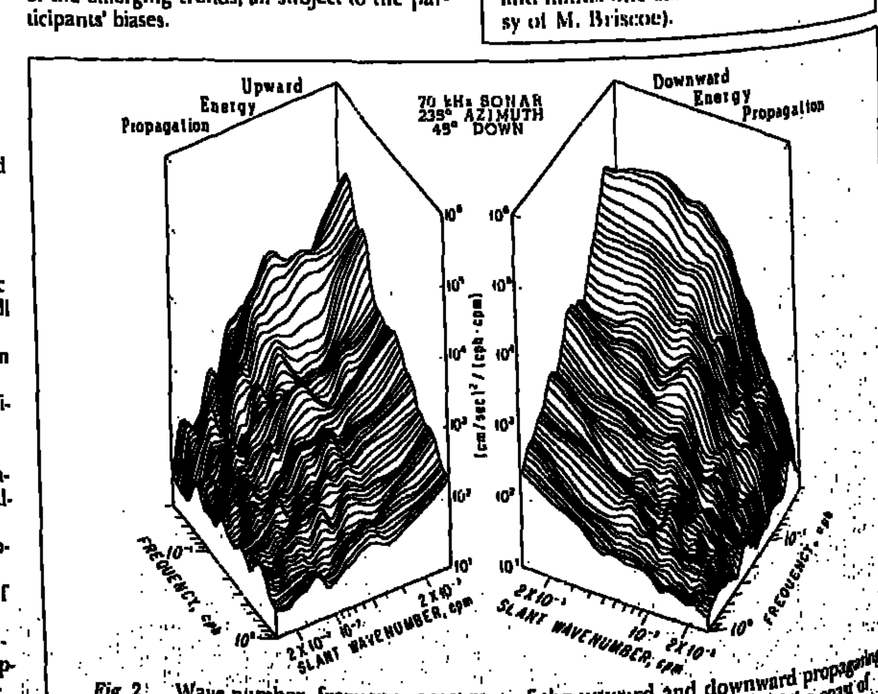

Fig. 2. Wave number–frequency spectrum of the upward and downward propagating internal wave energy. The spectra were measured with a Doppler sonar off the coast of southern California. The spectrum is representative of the internal wave field in the depth range from 80 to 600 m and over a period of 18 days (courtesy of R. Pinkel).

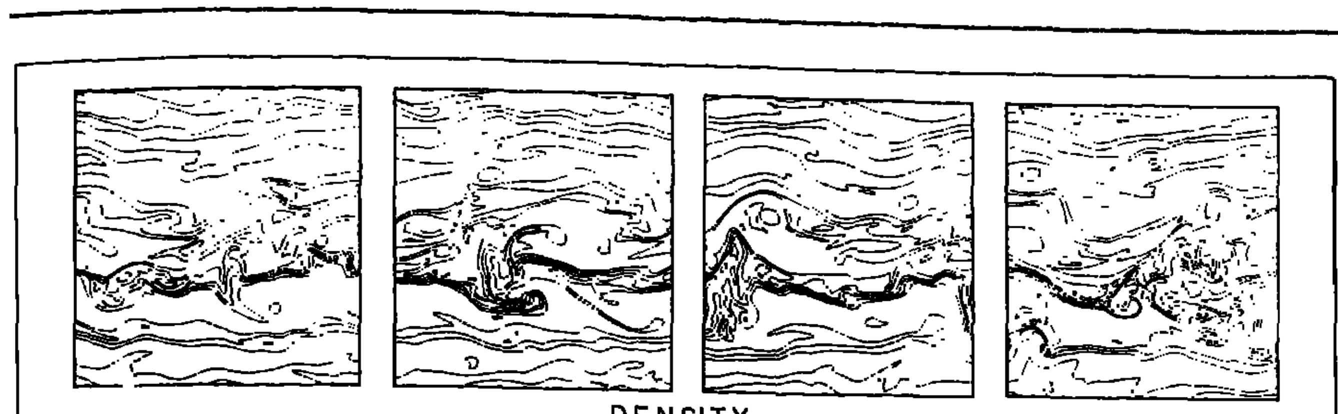

Fig. 3. Overturning of density surfaces in a two-dimensional simulation of strongly interacting internal waves. The domain represents a vertical plane, the lines isopycnals. The Richardson number of the flow is about 0.7. The frames are separated by about half a buoyancy period (courtesy of G. Holloway).

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Cover. The photograph shows a Roman scallop shell mosaic dating back to about A.D. 130–150. The border is a Hellinistic wave pattern, found in the earliest classical mosaics, those of about 400 B.C. at Olyntheus. The wave pattern closely resembles the billows observed in Kelvin-Helmholtz shear flow instability between two fluids of different densities. The instability is thought to be the cause for internal wave breaking and mixing in the ocean. The photograph is reproduced with the permission of the Director of the Verulamium Museum at St. Albans, U.K. (Photo submitted by Eric D'Asaro and Peter Müller. See meeting report in this issue of *The Oceanography Report* entitled "New Directions in Internal Wave and Microstructure Research.")

Sources and Sinks

Numerous sources and sinks have been proposed for the internal wave field [see, e.g., *Olbers*, 1983]. Observationally, the situation might be summarized as "a little bit of evidence for everything" (Briscoe). No dominant generation or dissipation mechanism has been identified, although some progress is occurring on some mechanisms.

Theoretical and observational evidence is emerging that the wind generates near-inertial frequency waves at large vertical scales (D'Asaro) and that internal waves and the mesoscale flow strongly interact (Watson).

Classically, it has been assumed that the internal wave field dissipates its energy predominantly in the interior of the ocean, through small-scale turbulence. Calculations (Eriksen) indicate, however, that the loss of internal wave energy at a sloping boundary might be substantial and could be the major energy sink of internal waves. Significant sinks of energy also may occur in critical layers when near-inertial waves become trapped within fronts or eddies [*Kunze and Sandford*, 1984]. These losses would be concentrated at particular locations in the ocean and not spread uniformly throughout its volume.

Current Fine Structure

Existing velocity and temperature measurements clearly show that linear internal waves alone cannot explain all of the observed structure within the internal wave frequency band [*Müller et al.*, 1978]. In particular, the coherence between current meters as a function of the vertical separation drops rapidly within the first few meters and then decays more slowly on a scale of many tens of meters. The rapid drop is traditionally attributed to current fine structure. At frequencies well above inertial frequency, current fine structure has an energy density comparable to that of internal wave motions. The kinematical and dynamical character of current fine structure is unclear. The traditional view is that it represents internal wave currents concentrated at small vertical scales because of the fine structure in the Brunt-Väisälä profile. A different view (Müller) holds that current fine structure is an entirely different type of motion with well-defined, distinct dynamics. Unlike internal waves, this "vortical mode" of motion [*Riley et al.*, 1981] carries potential vorticity. Current fine structure might, hence, be the small-scale realization of the same mode that represents quasigeostrophic flows at mesoscales.

The separation of internal waves and "vortical" motions is also a problem in the atmosphere. In meterology, the "vortical" mode is called "stratified two-dimensional (2-D) turbulence." The observed atmospheric mesoscale spectra are roughly consistent with theories of upscale inertial ranges in stratified 2-D turbulence (Lilly).

The implications of the existence of the vortical mode for the dynamics have not yet been explored, but we expect the vortical mode to be intimately connected and intertwined with the internal gravity mode of motion (Holloway). A distinction between the internal gravity and vortical mode of motion requires the measurement of vorticity on small scales, a measurement that to date has not been possible because of lack of suitable instruments; however, a "vorticity meter" is now being developed by Sanford (personal communication, 1984), so that such distinction might soon become possible.

Small-Scale Turbulence

If double diffusive effects are ignored, small-scale turbulence measurements are almost always discussed within the following, now classical, framework: Estimates of oceanic mixing rates can be made from velocity and temperature measurements that resolve the small scales on which molecular dissipation occurs. Measurements of the Richardson number on the meter scale commonly show values of the order of 1 or less, suggesting that shear instability is a major mechanism for mixing. Assuming that the shear responsible for the small values of the Richardson number is due to internal waves, dissipation driven by shear instability becomes an energy sink for the internal wave field. Accordingly, the rate of mixing and the properties of the internal wave field are related. If this link were understood, the rate of mixing could be parameterized in terms of the energy sources and environmental parameters of the internal wave field.

Studies of the relationship between small-scale turbulence and the internal wave field clearly require measurements of both the turbulence, using microstructure instruments, and the internal wave shear and density fields, using larger scale measurements. Existing evidence suggests that the internal wave field is highly random, so many measurements are required. Instrument systems capable of repeated measurements of both microstructure and internal wave scales have only recently become available (Gregg, Osborn) and are limited to use in the upper few hundred meters. Simultaneous measurements of the internal wave spectrum and microstructure over periods long enough for significant changes in the internal wave field to occur are not yet available. It is, therefore, not surprising that the research in this field is still exploratory.

If, as hypothesized, small-scale turbulence is driven by the internal wave field, its structure should reflect the structure of the wave field. Observationally, this issue is complicated by the possibility of turbulence caused by double diffusion which is ignored here. Nevertheless, several promising links between the internal wave field and oceanic turbulence are emerging.

Patchiness. Measurements of small-scale turbulence generally show that the individual mixing events are not randomly distributed, but concentrated into "patches" of high activity. These "patches" vary in size from centimeters to 10–20 m (Gregg, Dugan, Osborn, and Figure 4), with the smaller patches being more common.

Two theoretical approaches based on internal waves predict such a structure: Calculations of the vertical distribution of the Richardson number, Ri, made assuming a Garrett and Munk internal wave spectrum, and Gaussian statistics (Desaubies). If a turbulent patch is assumed to occur whenever $Ri < 1/4$, a range of "patch" sizes, comparable to that observed, is computed. A more detailed comparison with the observed "patch" statistics would be interesting. Eikonal calculations, which trace individual waves in a background internal wave spectrum, have also been used to model the spatial distribution of small-scale turbulence (Henyey). It is assumed that an individual wave breaks when it reaches a sufficiently high wave number. One such calculation shows the persistent clustering of the breaking events at a particular level, suggesting the formation of a turbulent "patch." This calculation suggests that it may be possible to formulate general criteria for the location of such patches as a function of the background shear field.

Recent experimental work suggests a link between the larger patches and near-inertial frequency shear. One such patch, which persisted for nearly a day, occurred at the same depth as a small inertial jet (Gregg).

Shear Statistics. The universal internal wave spectra have dominantly been energy spectra and have not accurately described the statistics of the shear and density gradient fields, particularly on scales smaller than 10 m. Such a description is needed if accurate models of the link between microstructure and internal waves are to be developed. A "universal" shear spectrum has been proposed by *Gargett et al.* [1981], but it is not complete. There is still uncertainty as to whether the shear at 10 m scales is dominantly inertial, as at larger scales (D'Asaro) or dominantly high frequency (Pinkel). This particular question is complicated by Doppler-shifting of small-scale velocity features. Basic descriptive work is needed on the shear and density gradient distribution, spectrally, spatially, and temporally.

Kelvin-Helmholtz Billows. A variety of ingenious arguments developed in the last decade allow K_ρ, the vertical diffusivity for mass, to be estimated from microstructure parameters; however, a clear picture of the three-dimensional structure and evolution of these mixing events has not yet emerged. Generally, mixing is envisioned as being caused by *Kelvin-Helmholtz billows. The structure of* these billows was very nicely depicted by the artist of the Roman scallop shell mosaic shown on the cover. These billows have been extensively studied in the laboratory and have been observed at one location in the upper ocean [*Woods*, 1968]. The extrapolation of laboratory studies to the ocean may be difficult, due to side-wall effects in the laboratory studies (Thorpe). A variety of other stratified shear flow instabilities with structures distinct from Kelvin-Helmholtz billows, such as wave breaking and critical layer absorption, have been observed in the laboratory [*Thorpe*, 1973] and may also occur in the ocean. Turbulence research in other fields has benefitted greatly from flow visualization studies that aim to identify the dominant structures of the turbulent flow. Once the structures of a flow have been identified in this way they can usually be identified in point measurement. It seems likely that similar studies using dye or high-frequency acoustics would likewise increase our understanding of oceanic turbulence.

On the theoretical side, the nonlinear stability of stratified flows has been investigated by using a constrained energy method due to V. I. Arnol'd (Abarbanel). Applied to the customary parallel shear flow in the presence of stratification, one proves that the flow is nonlinearly stable for Richardson numbers greater than unity. The theoretically interesting regime is hence $1/4 < Ri < 1$ where the flow is stable to infinitesimal perturbations, but *may be unstable to finite perturbations.* Shear-generated turbulence in homogeneous fluids is being studied with new second-order closures. Employed in numerical models, these yield good predictions of the observed Reynolds stress tensors evolving in strained *and sheared wind tunnel flows (Gallagher).*

Oceanography *(cont. on p. 380)*

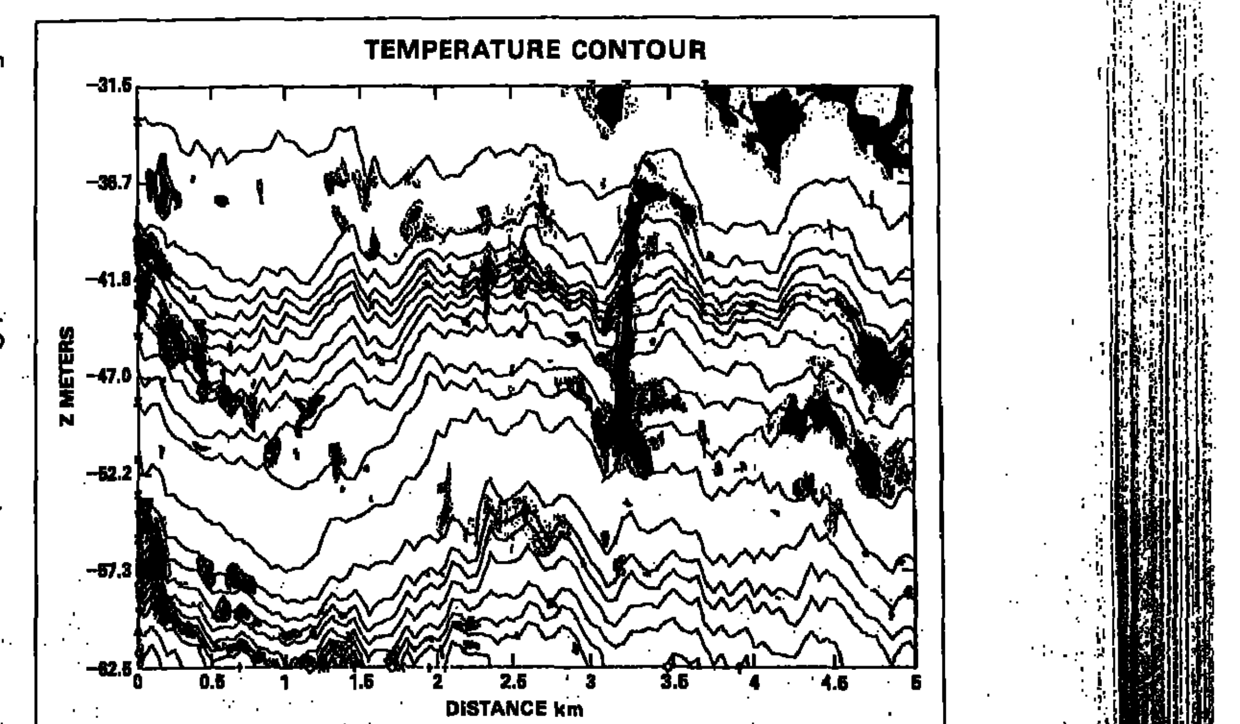

Fig. 4. Patches of microstructure in a temperature section. In the shaded areas the microstructure activity is 30% above the mean. The lines represent isotherms. The data are from the Sargasso Sea and were obtained with a thermistor chain towed at a speed of about 250 cm s^{-1} (courtesy of J. Dugan).

Oceanography (cont. from p. 379)

Parameterization

Many oceanographers prefer to study the large-scale motions of the ocean. These oceanographers regard internal waves and small-scale turbulence as subgrid-scale noise and ask for the parameterization of subgrid fluxes in terms of large-scale flow characteristics. They ask for eddy diffusion and viscosity coefficients. Here the state of affairs is still not satisfactory. Most work on parameterization has been concerned with the vertical diffusion coefficient K_v. A typical value of 0.1 $cm^2 s^{-1}$ seems not to be inconsistent with microstructure measurements and the kinematics and dynamics of internal waves (Garrett). A similar value is obtained when the observed large-scale hydrographic field is fitted by beta-spiral methods (Olbers) but that value includes an artificial contribution due to averaging of the data. Basic questions are still unanswered. For example, how much of the vertical mixing is done in the interior of the ocean and how much is done in boundary layers? Does the value K_v have a strong depth dependence? The answers to these questions could have dramatic implications. Changing the depth dependence of the dissipation rate changes the direction of the meridional circulation in an advective diffusive model of the thermohaline circulation (Gargett).

The momentum fluxes are even less established. There are only spotty measurements. Some of them imply significant eddy viscosity coefficients [e.g., *Brown and Owens*, 1981], but no coherent picture has emerged from the sparse data.

Conclusions and Trends

Internal gravity waves and small-scale turbulence are the motions by which the ocean mixes momentum and mass. The specific way in which this mixing is done has pronounced effects on geostrophic eddies and the general circulation. To understand these grander scales of motions, we must understand the smaller-scale mixing processes.

Internal wave research is presently undergoing a transition from a dominantly kinematic study of spectral slopes to a dominantly dynamic study of sources, sinks, and internal fluxes. The link between internal waves and oceanic turbulence is becoming more apparent, and the glimmers of a dynamical understanding are emerging. The parameterization of the internal wave and turbulent fluxes, which is a major goal of these studies, has not yet been achieved.

Further progress will come from simultaneous measurements of internal waves and microstructure and from a detailed comparison of experimental data with the results of numerical models. These experiments and studies require collaboration of oceanographers across specific areas of interest, a beginning of which was witnessed at the Hawaiian Winter Workshop.

Acknowledgments

The second 'Aha Huliko'a Hawaiian Winter Workshop on Internal Gravity Waves and Small-Scale Turbulence was supported by the Office of Naval Research. Hawaiian Institute of Geophysics contribution 1483. We thank all the participants of the workshop for their valuable ideas (many of which have gone unacknowledged here), and for their permission to quote unpublished materials.

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Article (cont. from p. 377)

eralizations of lower dimensional results.

From a hydrologic standpoint there is little doubt that temporal stochastic models will continue to be of importance in hydrologic research, particularly for small rural and urban basins over which the spatial variability in rainfall is not as appreciable. However, the inference procedures currently available for temporal models are only satisfactory for a handful of cases, for example, Markov chains, Poisson process, and renewal models. An important research direction in temporal modeling is to investigate the suitability of different stochastic models as dictated by the time scales of interest (e.g., hourly, daily). Furthermore, parameter estimation in such models needs to be addressed in relation to the availability of rainfall data on these time scales. It will be particularly important to address the issue of disaggregation/aggregation and the applicability of a model to time scales other than those for which the parameters are estimated. It seems that not much attention has been given to these important issues in precipitation research in the past.

Measurement of Precipitation

One limitation to the development of more accurate descriptions of the space-time structure of precipitation is the ability to measure precipitation. For space-time rainfall models, typical rain gauge networks seldom provide sufficiently detailed information for model testing. Although point data from rain gauges have relatively high accuracy, though a gauge catch error of "about 10%" is considered the norm for rainfall, in most locations the network of gauges is sparse in the sense that precipitation becomes uncorrelated in space over distances comparable to or less than the gauge spacing, at least during some types of events. The fine structure of precipitation in time also is beyond the time sampling interval of most rain gauge data.

Remote sensing technologies, such as those provided by radar and satellites can help fill in the space-time sampling gaps, but remotely sensed measurements are much more tenuously related to precipitation than gauge measurements. A well-maintained, well-calibrated radar can easily be in error by a factor of 2 or 3 in its precipitation estimates. Unusual atmospheric conditions can make obtaining quantitative estimates even more difficult. Satellite techniques also achieve much better spatial coverage than gauges but generally at reduced accuracy.

In addition to degrees of accuracy and space-time coverage, remote sensing technologies differ from gauges in sampling characteristics. Gauge values can be reasonably treated as point values with a fairly simple error model; white noise, for example. In contrast, remotely sensed values represent a space-time average of the precipitation field, corrupted by a wide variety of sensor, transmission, translation, and navigation errors. While it seems possible to establish the error characteristics of rain gauges directly by conducting wind tunnel tests and comparing results with highly accurate experimental gauges, more sophisticated procedures are needed to infer the error structure of remotely sensed observations. The problems associated with the error structure of remotely sensed precipitation estimates seem to have received little attention thus far in precipitation research.

The above issues clearly suggest that continued efforts to improve the accuracy of remotely sensed precipitation estimation technologies and techniques are needed. A better grasp of the nature of errors in precipitation measurements would be of considerable value because of their direct relation to the problem of statistical inference and model verification procedures. In this respect it would be beneficial to employ the advances in precipitation modeling to address the issues of network design problems. These problems are complex because of the need to address not only the sensor placement issues but also because of issues related to choosing a mix of sensors with different sampling characteristics. Another important role that advances in precipitation modeling can play is in the problems associated with merging rain gauge, radar, and satellite data. These areas clearly are in need of further comprehensive research. A related problem is the availability of precipitation data itself. Although the National Climatic Data Center maintains precipitation data from about 12,000 gauges, not all of these data are available in a timely fashion (i.e., there is quite a lag before much of the data are available).

Precipitation and "Operational" Hydrologic Forecasting

Operational hydrologic applications have a wide variety of needs for precipitation estimates and forecasts. For example, hydrologic design problems and real-time hydrologic forecasting produce distinctly different requirements on precipitation forecasts. Hydrologic forecasting involves time scales ranging from about an hour to a few days and requires quantitative precipitation forecasts based on current conditions. In hydrologic design the temporal resolution may be the same or considerably longer (e.g., months or years), but the data period considered frequently extends to several decades.

Long-range hydrologic forecasting naturally requires longer range precipitation forecasts. Procedures exist which produce probabilistic hydrologic forecasts for water supply, irrigation, riverine navigation, and hydropower applications with lead times from a week up to several months. Although these lead times exceed the capability of techniques which produce (the so-called) quantitative precipitation forecasts, improved capability to forecast the precipitation regimes in a probabilistic sense would be of direct value in long-range forecasting for the above applications as well as in hydrologic design.

Improvements in hydrologic forecast lead time (the difference in time between the time of the occurrence of the forecasted hydrologic phenomenon and the time when the forecast is issued) and accuracy can be achieved if reliable quantitative precipitation forecasts (QPF's) are available for specific watersheds as input to the hydrologic forecast models. Unfortunately, current QPF models and procedures generally do not provide sufficiently accurate values for direct input to hydrologic models, at least for forecast periods exceeding an hour. Although current QPF products provided by the National Meteorological Center (NMC) provide generalized guidance indicating rainfall amounts and locations of rainfall areas, they do not provide the detail and accuracy required for assigning QPF values to individual watersheds. There is a need for more direct incorporation of QPF information into hydrologic modeling and prediction procedures. This is especially important to the improvement of forecasts for small watersheds where the lag time between rainfall occurrences and outflow from the basin is short.

It is apparent that hydrologists are in a position to provide guidance on meteorological requirements for hydrologic forecasting. In this respect communication between hydrologists and meteorologists would be particularly useful in improving the hydrologic usefulness of short-term (e.g., 1 hour to 3 days) quantitative precipitation forecasts. A positive step in this direction is the assessment of operational quantitative precipitation forecasting procedures being prepared by the Office of Hydrology of the National Weather Service [*Georgakakos and Hudlow*, 1983]. Similarly, long-term forecasts are intended in part for water resources applications, yet there appears to be little coordination between hydrologists and meteorologists to ensure that the form and substance of forecasts conform to the applications.

Final Remarks and Recommendations

In the above paragraphs we have attempted to bring out the scope of research directions in precipitation studies and indicate an imperative need to promote and undertake interdisciplinary research on precipitation. It is clear that in order to accomplish this objective a strengthening of the mutual cooperation among hydrologists, meteorologists, atmospheric scientists, mathematicians, and statisticians is called for. We offer the following preliminary recommendations in order to initiate this undertaking.

A national STORM program is being organized by the U.S. meteorological community. STORM, derived from "Stormscale Operational and Research Meteorology," is the acronym for the U.S. Mesoscale Meteorology Program designed to study mesoscale atmospheric processes for improved short-range weather predictions. The need for improved quantitative precipitation forecasts is identified as one of the key problem areas.

Three field experiments are being planned for the STORM program. The first of these experiments, called STORM Central, is to take place in the spring and summer of 1988 in the central United States from the Rocky Mountains to the east of the Mississippi Valley, and from the Gulf of Mexico to the U.S.-Canadian border. The experiment will collect upper air and surface data with high spatial and temporal resolutions for 120 days over a 2000 × 2000 km area. It will provide a data set suitable for the study of precipitation processes and for the testing of precipitation models. No data sets with similar resolution and coverage have ever been collected. Many of these data can be used for hydrological studies.

We therefore recommend that the hydrological community actively participate in the planning of the experiment and in the analysis of the experimental data for hydrological studies. For this purpose, immediate actions are needed, first, to coordinate the planning of a network for collecting hydrologic data on basins in the central United States (e.g., streamflows, groundwater levels, soil moisture, evaporation, and evapotranspiration) and, second, to provide input to the STORM Central planning team for coordinating the collection of these data in conjunction with meteorological data.

In addition to the above, we would like to make the following recommendations: (1) that the Office of Hydrology of the NWS establish a working group to study the users' need for quantitative precipitation forecast; (2) that the National Climatic Data Center establish a hydrometeorological data archive designed for applications to various hydrological modeling and data analysis problems, including precipitation; (3) that 1–3 day symposia, workshops, or special sessions at AGU AMS/ASA or other conferences are organized; (4) that AGU publish monographs containing review papers; (5) that special issue(s) of appropriate journal(s) addressing important recent developments in precipitation are published; and (6) that research projects having strong interdisciplinary makeup are funded by NOAA/NSF/NASA/USGS and other agencies.

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News

Thunder Day Increase

A report issued by the Illinois State Water Survey concludes that annual values of thunder days for North America exhibited a general increase of about 15% from 1901 to 1945, followed by a general decrease of 10% from 1945 to 1980. A study of the variability of thunder days across North America showed a general decrease with time, particularly after 1940. A major finding of this study is that frequencies of thunderstorms over areas as large as the North American continent show major long-term trends.

The report, "Temporal Distribution of Global Thunder Days," summarizes the results of a 1-year study by Stanley A. Changnon, Jr., and Chin-Fei Hsu of the temporal variations of thunder-day records during 1901–1980 using quality weather records from weather stations scattered around the globe. A thunder day is recorded when one or more peals of thunder are heard anytime during the 24-hour period from midnight to midnight, which is consistent with the definition of a thunderstorm used at first-order weather stations since 1897. They found most stations in the northern hemisphere north of 45° latitude exhibited a general increase in thunder activity from 1901 to 1980. The project was funded by the National Science Foundation.

Data for the study was collected from 90 stations in North America and 131 stations elsewhere around the world. The stations in North America selected were those that had operated on a 24-hour basis for the period of 1901–1980. The data from most foreign stations had periods of record of only 30–50 years, which limited the investigations of trends in thunder days in areas outside of North America. The data were evaluated to check for shifts in thunder-day frequencies due to station relocation, for major discontinuities between station averages and area averages, and for possible changes in thunder frequencies due to potential noise problems, such as might be caused by increased air traffic near a station. These tests led to the conclusion that four stations (Atlanta, Ga.; Kansas City, Mo.; Portland, Maine; and Toronto, Ont., Canada) had records that were incorrect and so were not used. These tests were not applied to the foreign stations because of a lack of station histories.

Examination of the temporal distributions of thunderstorms was done in several ways, including factor analysis and other statistical tests. The continent was first divided into four sectors with divisions at 100° W longitude and 40° N latitude, and temporal distributions in each sector were determined. Analysis confirmed that there were major regional differences in temporal frequencies of thunder days across North America. General increases in frequencies from 1901 to 1980 were found in the northwest and northeastern sectors. The southwest sector frequencies generally increase in the first 45 years and then rapidly descrased in the following 10 years. Relatively low frequencies were experienced from 1956 to 1980. The southeast sector exhibited little trend until 1930, followed by a general decrease until 1980.

Stations with similar 5-year average values were classified into regions of similarity. This classification method produced 14 regions in the United States and Canada, which themselves fell into two major regions. One was the northern United States and all of Canada, where all stations exhibited a general increase in thunder-day frequency, and the other was the southeastern third of the United States, which exhibited a major decrease in thunder-day frequencies after 1925. A narrow transition zone separated the two major regions.

The 14 regions in North America can be related to major climatic zones such as differences in major air mass sources, particularly in summer, areas of cyclogenesis, and location of major cyclone tracks. the southeastern United States, for which there was a major decrease in thunder-day frequency, is an area of major industrial development and pollution in the United States, and the decrease may or may not be related to possible man-made influences.

The report concludes that the major temporal variations in thunder days were largely due to major shifts in the atmospheric circulation, reflected in the continental scale frequencies of cyclonic storms. Historical regional data on cyclone frequencies in North America would be useful in identifying the regional trends found. Comparison of thunder days with actual thunderstorm durations and other measures of atmospheric electricity are needed to help assess any temporal fluctuations in lightning discharge activity.

This news item was contributed by Steven D. Hilberg, *Extension Services Coordinator, Illinois State Water Survey, Champaign, IL 61820.*

MORP: Keeping Track of Meteorites

If one considers the level of significance frequently granted to observations of small portions of an individual meteorite sample, the question of sampling error arises. A project to answer this question has been underway in Canada for 9 years (1974–1983). The Meteorite Observation and Recovery Project, or, more simply MORP, is an observational network designed to evaluate the frequency of meteorite falls on the surface of the earth [see I. Halliday, A. T. Blackwell, and A. A. Griffin, *J. R. Astron. Soc. Can.*, *72*, 15, 1978]. Other major networks for observation have been operative in the United States and Central Europe. Halliday, Blackwell, and Griffin reported recently on MORP results: ". . .the total mass deposited on the ground is 142 kg $year^{-1}$ in 10^6 km^2. . .it is obvious that a very small portion of the potential harvest is ever located" [*Science*, *223*, 1405–1407, 1984]. The actual numbers from the analysis are staggering. The normal recovery rate of meteorites per year in the world is no more than one or two dozen (excluding "fossil" meteorites recovered from the Antarctic glacial ice). The number of meteorite falls over the entire earth's surface is about 25,000 per year, according to the MORP analysis.

The basis of the analysis is photographic observation of fireballs in an area of clear sky. Meteors were observed by at least two camera stations at an altitude of at least 8°. The MORP results turned out to be an observation of 1.16×10^{10} km^2 hours over the 9 year period. Analysis of the photographs were used to calculate masses and categorize the meteors. Halliday et al. used as calibration, the observation and recovery of the Innisfree fall [*Meteorites*, *16*, 153, 1981].

Figures predicted by meteor sample mass give a clear picture of the sampling problem. In North America, the annual numbers of meteorite falls for total masses of 0.1, 1, and 10 kg per fall was 920, 1980, and 38. For the entire land area of the earth the annual numbers for the three mass categories were 5800, 1200 and 240. Other calculations could be made to estimate the number of ore objects that survive the earth's atmosphere and reach the surface. Further, the estimates could be extended to encompass the earth-moon system of the solar system.— *PMB*

Research Roundtable

A blue-ribbon panel of government, university, and industry leaders has been established to explore alternative approaches to strengthening their relationships.

The 18 member Government-University-Industry-Research Roundtable Council, organized as an independent unit under the aegis of the council of the National Academy of Sciences (NAS), will address issues affecting and limiting the vitality of science in the United States. Thirteen of the 18 members are from universities and industry; 5 are senior federal officials. Dale R. Corson, president emeritus of Cornell University, is chairman of the roundtable council.

The council is the overall guiding group for the ongoing research roundtable, according to Don I. Phillips, council executive director. The council, which plans to meet three times a year, will spawn ongoing activities (including workshops, working groups, and special studies) to keep communication open among relevant groups.

At its first meeting on May 17 and 18, the roundtable council agreed on a broad and comprehensive framework of issues. The theme overriding the framework is the need to establish, strengthen, and maintain a network among relevant groups to keep the lines of communication open. The research roundtable will focus initially on three issues: the relationship of science and technology to economic competitiveness; the renewal of scientific and technical institutions (including upgrading facilities and equipment, enhancing technology transfer, and the new partnerships between universities and state governments and between universities and industry); and the enhancement of communications between scientists, industry employees, and government employees at the working level.

The roundtable was formed following the identification by several NAS panels of the need for an ongoing, neutral body to improve the communication and mutual understanding among those who fund research, those who carry it out, and those who use the results. NAS provided initial funding. Additional support has been made available by the Alfred P. Sloan Foundation and the Andrew W. Mellon Foundation.

In addition to chairman Corson, other members of the roundtable council are William G. Anlyan, Chancellor for Health Affairs, Duke University Medical Center; Kenneth J. Arrow, Joan Kenney Professor of Economics, Stanford University; Marvin Cohen, Professor of Physics, University of California, Berkeley; Edward G. Jefferson, Chairman of the Board, E.I. DuPont de Nemours & Co., Inc.; Sol Linowitz, Coudert Brothers Law Firm, Washington, D.C.; George E. Pake, Vice President for Corporate Research, Xerox Research Center; Alexander Rich, Sedgwick Professor of Biophysics, Massachusetts Institute of Technology; Howard A. Schneiderman, Senior Vice President for Research and Development, Monsanto Co.; Harold Shapiro, President, University of Michigan; Robert L. Sproull, President, University of Rochester; and Linda S. Wilson, Associate Vice Chancellor for Research, University of Illinois, Urbana.

Participating federal officials are Richard D. DeLauer, Undersecretary of Defense for Research and Engineering, U.S. Department of Defense; George A. Keyworth, II, Director of the Office of Science and Technology Policy; Edward A. Knapp, Director, National Science Foundation; Alvin W. Trivelpiece, Director, Office of Energy Research, U.S. Department of Energy; and James B. Wyngaarden, Director, National Institutes of Health. Frank Press, NAS President, is an ex officio member.

The next meeting of the research roundtable council is scheduled for November 29 and 30.

Viking Lander 1: New Exhibit

The National Aeronautics and Space Administration (NASA) transferred ownership of the Viking Lander 1, which landed on Mars in 1976, to the Smithsonian Institution's National Air and Space Museum.

Requested by museum director Walter Boyne, the transfer includes the loan of the official Viking Lander plaque, which renames the lander the Thomas A. Mutch Memorial Station in memory of the Viking Lander imaging team leader and NASA associate administrator for space science. Mutch died in a climbing accident in the Himalayas in 1980. The plaque is scheduled to be placed on Mars by U.S. astronauts at some indefinite time. NASA retains reclaimant rights of the lander for scientific purposes.

This is the first time that a museum will own an object located on another planet. Tourist visitation at the new exhibit is not yet expected to rival traffic at the parent museum.

U.K. Radio Science Reviews Available

Coincident with its triennial general assemblies, the International Union of Radio Science (URSI) publishes an international review of the most significant scientific developments over the previous 3 years in the nine subject areas covered by URSI's commissions. To produce this review, international editors distill reviews from each member country of national scientific developments. For those scientists who wish to know more details about the significant scientific developments in radio science in the United Kingdom from 1981 to 1984, the British National Committee for Radio Science has made its reviews available.

Unless otherwise noted, the following surveys are available from the Royal Society, 6 Carlton House Terrace, London SW1Y 5AG, Attention: C.R. Argent.

Commission A: Electromagnetic meteorology, by J. M. Steele; available from J. M. Steele, National Physical Laboratory, Teddington, Middlesex, TW11 0LW.

Commission B: Fields and waves, by P. J. B. Clarricoats.

Commission E: Interference environment, by F. Horner.

Commission F: Remote sensing and wave propagation, by E. D. R. Shearman.

Commission G: Ionospheric radio and propagation by P. A. Smith; available from J. W. King, Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire OX11 0QX.

Commission H: Waves and plasmas, by P. A. Smith; available from J. W. King, Rutherford Appleton Laboratory, Chilton, Didcot, Oxfordshire OX11 0QX.

Commission J: Radio astronomy, by D. H. Martin; available from D. H. Martin, Department of Phyiscs, Queen Mary College, Mile End Road, London E1 4NS.

Geophysicists

Recently elected as officers of the Brazilian Hydrology and Water Resources Association are ***Antonio Carlos Tatit Holtz***, president; ***Antonio Eduardo Leão Lanna***, vice president; and ***Ciro Loureiro Rocha, Gilberto Valente Canali***, and ***Orlando Vignoli Filho***, directors. The new mailing and secretariat address is Associação Brasileira de Hidrologia e Recursos Hídricos—ABRH, A/C Gilberto Valente Canali, ELETROSUL/DIVH, Rua Deputado Antonio Edu Vieira, s/no—Pantanal, 88000 Florianópolis, SC, Brasil.

In Memoriam

Johannes Theodoor Thijsse, 91, died April 30, 1984. An AGU Life Fellow and a member of the Hydrology Section, he joined AGU in 1948.

Recent Ph.D.'s

Eos periodically lists information on recently accepted doctoral dissertations in the disciplines of geophysics. Faculty members are invited to submit the following information, on institution letterhead, above the signature of the faculty advisor or department chairman:

(1) the dissertation title,
(2) author's name,
(3) name of the degree-granting department and institution,
(4) faculty advisor,
(5) month and year degree was awarded.

If possible, include the current address and telephone number of the degree recipient (this information will not be published).

Dissertations with order numbers, and many of the others listed, are available from University Microfilms International, Dissertation Copies, P.O. Box 1764, Ann Arbor, MI 48106.

Iodide Enhanced Electron-Capture Detection of Halocarbons with Application to Atmospheric Methyl Chloride, Gwendolyn Louise Ball, Univ. of Mich., 1983 (GAX84–02238)

The Kinetics of Sorption Reactions at the Geothite-Aqueous Interface (Desorption, Rate), Kerry Kiphart, Univ. of Notre Dame, 1983, (GAX84–03954).

Kinetic Studies of the Thermal Decomposition of Methylperoxynitrate and of Ozone-Olefin Reactions, Abraha Bahta, Penn. State Univ., 1983 (GAX83–27470).

Martian Paleoclimate, Susan Elaine Postawko, Univ. of Mich., 1983 (GAX84–02360).

Mean and Time-Dependent Motions in the Blake Escarpment Region, David Yuekchung Lai, Univ. of Rhode Island, 1983 (GAX84–01410).

Measurement and Analysis of Diffuse Solar Irradiance, Clifford Bruce Baker, Univ. of Mich., 1983 (GAX84–02235).

Miocene Stable Isotope Stratigraphy and Paleoceanography (New Zealand, Spain, Pacific Ocean), Tom Stuart Loutit, Univ. of Rhode Island, 1981 (GAX83–28479).

I, A Multi-Tracer Study of the Abyssal Water Column of the Deep Bering Sea, Including Sediment Interactions. II, A Six Zone Regionalized Model for Bomb Radiotracers and Carbon Dioxide in the Upper Kilometer of the Pacific Ocean, John R. Toggweiler, Columbia Univ., 1983 (GAX83–27310).

Neotectonics of the North Frontal Fault System of the San Bernardino Mountains, Southern California: Cajon Pass to Lucerne Valley (Structure, Slip-Rate, Hazard), Kristian Erik Meisling, 1984 (GAX84–02492).

Photochemical Modeling of the Earth's Stratosphere, Lucien Froidevaux, Calif. Inst. of Tech., 1984 (GAX84–02489).

Prediction of Atmospheric Flow and Dispersion Over Sloping Terrain, Eueng-Nan Yeh, Univ. of Utah, 1983 (GAX84–02162).

Reaction Mechanisms and Chromatographic Behavior of Polyprotic Acid Anions in Multicomponent Ion Exchange (Arsenic, Groundwater), Liou-Liang Horng, Univ. of Houston, 1983 (GAX83–28886).

Reactions of Mutagenic Propylene Oxides with Deoxynucleosides and DNA, Zora Djuric, Univ. of Mich., 1983 (GAX84–02272).

Rock Geochemical Exploration at Mount Morgan, Queensland, Australia, Mark Albert Fedikow, Univ. of New South Wales (Australia), 1982.

Sedimentary Response to Eocene Tectonic Rotation in Western Oregon (Washington, Pacific

News (cont. on p. 382)

News *(cont. from p. 381)*

Northwest, Petrology), Paul L. Heller, Univ. of Ariz., 1983 (GAX84-01264).

Sedimentology and Invertebrate Paleontology of Triassic and Jurassic Lacustrine Deposits, Culpeper Basin, Northern Virginia, Pamela J. Wheeless Gore, 1983 (GAX84-01325).

Stratigraphic, Geochemical, and Petrologic Studies of the Ammonoosuc Volcanics, North-Central Massachusetts and Southwestern New Hampshire, John Charles Schumacher, Univ. of Mass., 1983 (GAX84-01103).

Structure of the Brevard Zone and Blue Ridge Near Lenoir, North Carolina, With Observations on Oblique Crenulation Cleavage and a Preliminary Theory for Irrotational Structures in Shear Zones, Andy R. Bobyarchick, State Univ. of N.Y. at Albany, 1983 (GAX84-01429).

The Upper Proterozoic Redstone Copper Belt, Mackenzie Mountains, N.W.T., Charles W. Jefferson, Univ. of Western Ontario (Canada), 1983.

The Vertical Redistribution of a Pollutant Tracer Due to Cumulus Convection, John Andrew Ritter, Univ. of Mich., 1983 (GAX84-02364).

Watershed Acidification Model and the Soil Acid Neutralization Capacity Concept, William G. Booty, McMaster Univ., Canada, 1983.

An X-Ray Scattering and Raman Spectroscopy Study of Iron (3+), Gallium (3+) and Germanium (4+) Substituted Aluminosilicate Glasses, Grant S. Henderson, Univ. of Western Ontario (Canada), 1983.

Geophysical Events

This is a summary of *SEAN Bulletin*, 9(4), April 30, 1984, a publication of the Smithsonian Institution's Scientific Event Alert Network. The complete bulletin is available in the microfiche edition of *Eos* as a microfiche supplement or as a paper reprint. For the microfiche, order document E84-005 at $2.50 (U.S.) from AGU Fulfillment, 2000 Florida Avenue, N.W., Washington, DC 20009. For the paper reprint, order *SEAN Bulletin* (giving volume and issue numbers and issue date) through AGU Separates at the above address; the price is $3.50 for one copy of each issue number for those who do not have a deposit account, $2 for those who do; additional copies of each issue number are $1. Subscriptions to *SEAN Bulletin* are available from AGU Fulfillment at the above address; the price is $18 for 12 monthly issues mailed to a U.S. address, $28 if mailed elsewhere, and must be prepaid.

Volcanic Events

Rabaul (New Britain): Caldera earthquakes up 60%, two seismic crises: expansion and uplift double.
Manam (Bismarck Sea): Strong strombolian activity; debris avalanches.
Langila (New Britain): Occasional vulcanian explosions for 10 days.
Campi Flegrei (Italy): Seismic energy release and uplift slow after April 1 earthquake swarm.
Etna (Italy): Strombolian activity and small lava flows from SE crater.
Home Reef (Tonga Is.): Large pumice rafts; new island shown.
Submarine Volcano (Izu Is.): Acoustic waves recorded in French Polynesia.
Macdonald (S-central Pacific): Renewed submarine activity in 1983.
Teahitia (French Polynesia): Seismic swarms indicate two submarine eruptions.
Kilauea (Hawaii): 18th phase; four flows, longest flow of 1983–1984 eruption.
Mauna Loa (Hawaii): Major NE Rift Zone eruption ends; total eruption volume.
Mt. St. Helens (Washington): Mud flow and vertical plume.
Veniaminof (Alaska): Vapor clouds; ash plume to 2 km altitude; no glow.
Pagan (Mariana Is.): Dark eruption columns.
Atmospheric effects: Stratospheric aerosols decrease.

Rabaul Caldera, *New Britain Island, Papua New Guinea (4.27°S, 152.20°E). All times are local (= UT + 8 hours).*

The following is from Peter Lowenstein. "A further intensification of seismic activity in the Rabaul Caldera took place in April. The total number of caldera earthquakes was 13,749, 60% more than in March (the March total was 8729; see last month's *Bulletin*). Seismicity was concentrated on the E side of the caldera, in Greet Harbour and at the entrance to Blanche Bay.

"Major seismic crises occurred on April 21 and 22, when 1011 and 1717 events were recorded. The crisis on April 21 was centered at the mouth of Blanche Bay, and the strongest earthquake was a magnitude (M_L) 3.8 event. Only minor ground deformation was associated with this crisis.

"On April 22 at 1100 an M_L-4.8 earthquake heralded the most energetic crisis to date, which was centered at the head of Greet Harbour. Structural damage in this and the Sulphur Creek area included cracking, and in one case collapsing, of masonry walls, cracks in concrete floors, a burst water main, and burst household water tanks. This ground Greet Harbour ranged from 50 to 80 microradians, generally showing a pattern of radial inflation centered in the Harbour. Measurements of horizontal deformation indicated expansion of the Greet Harbour area by 20–30 microstrain.

"The overall pattern of ground deformation in April indicated that the strongest tilting, of up to 80 microradians, was in the Greet Harbour area. Rates of horizontal deformation indicated expansion was about double that in any previous month (40–50 microstrain).

"Leveling surveys from Rabaul Township to Matupit Island and around Greet Harbour showed that between mid-March and mid-April the S end of Matupit Island rose 76 mm. Further uplifts of about 50 mm on Matupit Island and at the head of Greet Harbour accompanied the April 22 seismic crisis, making the total uplift in April about double that in any previous month."

Information Contact: Peter Lowenstein, Principal Government Volcanologist, Rabaul Volcano Observatory, P.O. Box 386, Rabaul, Papua New Guinea.

Home Reef Volcano, *Tonga Islands, S Pacific (18.99°S, 174.78°W). All times are local (= UT + 13 hours).*

An early March eruption of Home Reef produced large quantities of pumice, ejected an eruption cloud to more than 12 km altitude, and built a new island (see *Eos*, March 27, 1984). Tonga government geologist David Tappin reported that brown discolored water preceded the eruption, which started March 1–2. The new island was visible by March 2. When Captain Jeff Heard of South Pacific Islands Airways flight 607 flew over the eruption site on March 5 at 1030, explosive activity had declined. Weak steaming occurred from a submarine crater surrounded by the new island.

In mid-March, a cargo vessel traveling from Tonga to Fiji at 12 km per hour took 9 hours to pass through a zone of pumice. Samples were collected from this vessel about 150 km W of Tonga. Pumice rafts were reportedly sighted at Oneata Island, Lau Group (18.45°S, 178.50°W, roughly 500 km WNW of Home Reef) on April 5. On May 1, ships between Tonga, Fiji, and Samoa reported that floating pumice was so thick that it was clogging their seawater intake systems.

Personnel from the Royal New Zealand Air Force (RNZAF) flew over the new island March 23. They gave its location as 19.02°S, 174.73°W, about 10 km S of Late Island. Dimensions of the new island were estimated at 1500 m by 500 m, with cliffs about 30–50 m high. Discolored water just NW of the island suggested submarine activity. Photographs taken from upwind showed the island to be yellowish brown in color, but atmospheric haze caused it to appear dark brown from downwind. David Tappin reported that activity was continuing in early April.

The Réseau Sismique Polynésien (RSP) did not record any seismicity from the eruption. Islands and deep water between Tahiti and Tonga prevented RSP stations from recording any acoustic waves (T-phase).

Information Contacts: David Tappin, Government Geologist, Nukúalofa, Tonga; Warrant Officer P. J. R. Shepherd, 1 SQN ALM LDR, RNZAF Whenuapai, Auckland, New Zealand; J. H. Latter, DSIR Geophysics Division, P.O. Box 1320, Wellington, New Zealand; J. Lum, Ministry of Energy and Mineral Resources, Private Mail Bag, Suva, Fiji; Ram Krishna, Director of Meteorology, Fiji Meteorological Service, Private Mail Bag, Nandi Airport, Fiji; J.M. Talandier, Directeur, Laboratoire de Géophysique, Commissariat á l'Energie Atomique, B.P. 640, Papeete, Tahiti, Polynésie Française; Norman Banks, USGS Hawaiian Volcano Observatory, Hawaii Volcanoes National Park, Hawaii 96718 USA.

Teahitia Volcano, *Society Islands, French Polynesia, S Pacific Ocean (17.57°S, 148.86°W).*

From August 1983 to March 1984, the Réseau Sismique Polynésien (RSP) recorded numerous sequences of low-frequency volcanic tremor and two seismic swarms associated with shallow submarine eruptions at Teahitia. On December 20–21, 300 very small earthquakes were recorded. On March 3 to April 15, 1984, approximately 9000 earthquakes were recorded, accompanied by low- and high-frequency spasmodic and harmonic tremor. Teahitia, a seamount with a summit about 2 km below sea level, was the site of seismicity associated with submarine eruptions detected by the RSP in March-April 1982 and July 1983 (see *SEAN Bulletins*, 7(4), and 8(8)).

Information Contact: J.M. Talandier, Directeur, Laboratoire de Géophysique, Commissariat á l'Energie Atomique, B.P. 640, Papeete, Tahiti, Polynésie Française.

Earthquakes

Information Contact: National Earthquake Information Service, U.S. Geological Survey, Stop 967, Denver Federal Center, Box 25046, Denver, CO 80225 USA.

Meteoritic Events

Fireballs: Papua New Guinea; Hawaii, Mississippi River Valley, USA.

Correction

The names of the people who wrote the tribute for Mahdi S. Hantush, which appeared May 22, 1984, were inadvertantly left off of the article. They are M. U. Ahmad, Ohio University, Athens, Ohio; G. W. Gross, New Mexico Institute of Mining and Technology, Socorro, New Mexico; M. A. Marino, University of California, Davis, California; S. S. Papadopulos, S. S. Papadopulos and Associates, Inc., Rockville, Maryland; and Z. A. Saleem, Ebasco Services, Inc., Greensboro, North Carolina.

Earthquakes

Date	Time, UT	Magnitude	Latitude	Longitude	Depth of focus	Region
April 23	0136	4.1 m_{bLg}	39.85°N	76.26°W	6 km	SE Pennsylvania
April 24	2115	5.7 m_b, 6.1 M_s*	37.23°N	121.76°W	10 km	Central California
April 29	0503	5.1 m_b, 5.6 M_s	42.92°N	12.14°E	shallow	Umbria, central Italy

*6.2 M_L at University of California, Berkeley.

Books

Carbon Dioxide Review: 1982

William C. Clark (Ed.), Oxford University press, New York, xi + 469 pp., 1982.

Reviewed by K. Ya. Kondratyev

A series of publications appeared in 1982 on climatic implications of increases in CO_2 concentration. Analyzing the status of numerical modeling of CO_2 impact on climate, M. Schlesinger (Oregon State University) has compiled a summary of 66 models, which is, nevertheless, quite inadequate, since Soviet studies as well as some other investigations have not been considered. All these studies show that the recently growing interest in the problem of anthropogenic effects on climate is far from abating, which is quite natural in view of the enormous practical implications of the climate change problem.

Since no climatic consequences of CO_2 increase have been observed so far, the major way of studying this effect has been numerical simulation of varying complexity, aimed first at an approximate assessment of possible changes in mean global climate (characterized by air surface temperature), and then in zonal and regional climates considered in sophisticated three-dimensional models. Though the estimates of mean global climate warming, on the assumption of a doubled CO_2 concentration, vary widely, most of the experts believe that the value 3 ± 1.5°C is most likely. However, this conclusion is inconsistent with the results of studies carried out by R. E. Newell and T. G. Dopplick and by S. B. Idso. Their results show that mean global warming should be about an order of magnitude less. However, their work has been severely criticized and considered erroneous (old that obviously overestimated values of CO_2 warming have not been so radically criticized).

In this connection three problems must be thoroughly dealt with: (1) the reliability of predicted estimates of CO_2 increase, (2) the reliability of current numerical climate models, and (3) the possible impact of the increased CO_2 concentration on the biosphere. These and the possible effects of climate change on industry and agriculture are the problems considered in *Carbon Dioxide Reviewed: 1982*. The editor of the book justly notes in the preface that during the recent decade the CO_2 climatic implications have often been overestimated, and, therefore, an objective analysis of the status of the problem is needed in addition to "official" assessments. The book consists of part 1, in which the problem is considered on the whole, and part 2, in which seven rather substantial essays on key aspects of the CO_2 problem are followed by comments of "opponents." The style of part 2 results in both more objective and more vivid presentation of the material, and the highly qualified participants of the dialogue ensure its rich scientific content.

The main goal of the authors is to reveal the commonly agreed upon aspects of the problem (based on reliable scientific arguments), and to analyze uncertainties, unsolved problems, and possible ways of their solution. The authors of the book have, on the whole, reached the goal, but sometimes they have not been sufficiently careful when formulating their conclusions, though the spectrum of various opinions has been rather impressive. For instance, concerning predicted estimates of the projected concentration increase of CO_2 (page 4), it is still not clear what level the CO_2 concentration will reach at a given time at the given CO_2 injection rate, because the role of the ocean biota in the global carbon cycle and the contribution of the continental biosphere require further investigation. Thus it is impossible to reliably estimate the CO_2 concentration doubling time (and there are reasons to believe that a doubling will never happen at all).

It is correct (page 22) that the possibility of the biological control of geochemical cycles must be thoroughly analyzed. It is not correct that climate changes are caused only by external impacts (page 5) such as solar variations, volcanic aerosols, and "greenhouse" gases. In fact, an internal variability of the climate system is also very important. In the very beginning the "scenario-type" character of the current estimates of CO_2 climatic implications should have been emphasized because (1) the forecasts of CO_2 increase are not reliable enough and (2) the adequacy of climate models, which are still unable to reproduce real climate variability, is limited (this was done only in the essay by R. E. Dickinson). In this connection a note is very important (page 21) on the connection between the CO_2 concentration veriations and climate. It follows from analysis of ice cores that a CO_2 concentration increase in the past could have been caused by climate warming, but not vice versa. The statement on pages 23–24 that the effect of clouds on climate warming is manifested only as a positive feedback is dubious. In this connection, it would be important to note that the current impossibility of reliable consideration of cloud-radiation interaction is one of the main causes of uncertainties of the predicted climate. If an increase of CO_2 leads to even a small increase of cloud amount, then a cooling, not a warming, of climate is quite possible. The book reviewed is an important contribution to the literature on climatic implications of CO_2 increase. Naturally a host of authors has produced a rather controversial picture. This, however, reflects the extreme complexity of an interdisciplinary problem still far from being solved. The book will be of great interest to specialists in various aspects of the climate problem. The writing style will also make the book accessible to a wide circle of interested nonspecialists.

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Frontiers of Hydraulic Engineering

Hung Tao Shen (ed.), American Society of Civil Engineers, New York, xv + 617 pp., 1983.

Reviewed by Raphael G. Kazmann

It is an impossible task for one person to review the proceedings of a major conference that consists of 141 different papers (including 26 one-page summaries of poster sessions). The papers are arranged into 35 technical sessions including Cohesive and Non-Cohesive Sediment Dynamics, Cold Regions Hydraulics, Computational Hydraulics, Groundwater Quality Modeling, Mixing Processes in Stratified Environments, Probablistic Approach to Hydraulics, and Surface Water Hydrology. The subject matter of many of the papers was familiar to the writer, specifically those concerned with groundwater and the hydrology, and hydraulics, of surface water. In addition, such topics as coastal dynamics, mixing processes in stratified environments, cohesive sediment dynamics (?), sediment resuspension and transport, and the hydraulic effects of ice cover are all to found in this volume. The writer refrains from comment on these papers except to say that although some of the papers were comprehensible, his experience is not basis enough for evaluation.

The title of the volume is a trifle misleading; about 70% of the papers have little to do with engineering, if engineering is considered to be concerned with accomplishment in the real world. Most of these papers deal in abstruse and theoretical constructs, based on assumptions that may easily be in error. Most papers rely heavily on computer models and mathematical approximations of all kinds, with little or no field data that might lead one to try to apply the results in a similar situation. Judging from the title of the book we might have expected to find more papers dealing with the application of current and proposed theory to the serious problems confronting the engineering profession. Perhaps a more accurate title for this volume would be *Frontiers of Hydraulic Research*.

Among the papers of general interest is an overview of dam safety by Bivens. We learn that in 1982 the U.S. Corps of Engineers reported to Congress that some 91% of the approximately 65,000 dams inspected were earth-fill. About 21,000 of the 65,000 dams had significant or high hazard potentials. Of those studied intensively by the time the report was completed, more than 80% possessed inadequate spillways. One of the frontiers of hydraulic engineering (and hydrologic engineering) must be the design of more adequate spillways. Another paper on the topic of dam safety, by Yang and Luebke, deals with risk assessment and illustrates the possible trade offs between costs of spillway improvements and annualized damages.

The sedimentation produced by the Mount St. Helens eruption was closely studied, and many field data were obtained. One method of forecasting deposition of the sediments is numerical modeling, and a paper by Brown and Thomas describes the approach and compares the field observations with the predictions. If the volcano continues to erupt, the model will receive much use and repeated field verification which will enable it, or a modified version of it, to be used with some confidence by the engineering profession.

Another paper, by Moss and Thomas, describes the attempt by the U.S. Geological Survey (USGS) to determine the effectiveness of its stream-gauging program. The USGS operates approximately 15,000 stream gauges in the United States of which some 8,000 are equipped with continuous recorders. The question addressed is, Are the records worth the money being spent, or could the same funds be spent in a more cost-effective manner? The authors estimate that some 5–10% of the continuous records could be replaced by part-time operation of recorders, the development of a flow routing model that would generate synthetic flows that would adequately serve the same purpose, or development of a regression model of flow at the site of interest whose results would compare properly with flows at other sites. They describe a prototype study of 51 continuous stream gauges that is designed to test their proposals, especially one called The Traveling Hydrographer, which is designed to allocate among stream gauges a predefined budget for the collection of field information in the most cost effective manner. One topic not addressed is how the increasing urbanization of watersheds combined with improvements in agricultural drainage will affect the stream-gauging program since none of the proposed substitutes for continuous records can be expected to yield the information needed in those situations.

The groundwater papers in this volume were disappointing. Of the seven papers dealing with groundwater quality modeling, one paper is just an abstract, five are mathematical models with no field data and no suggestions as to how they might be used by a practicing engineer. One paper, by Freyberg, MacKay, and Cherry, does contain data from a field experiment, but no attempt is made to answer the question, How can the results be used?. These may be "frontier" papers, but they are on the frontiers of something other than engineering. Perhaps they represent frontiers of research in groundwater hydraulics.

The papers on cavitation prevention and its mitigation are, as a group, probably the most practical. Five of the eight papers on the topic deal with aeration devices in hydraulic structures, and, as an example, one of these papers, by DeFazio and Wei, describes an analytical procedure which combines analysis of the flow of an ideal fluid, with an empirical equation and compares the results with actual observations. A paper by Falvey presents criteria, based on observations of damage in the field and practical constraints on construction, for a flow-cavitation index, to help anticipate cavitation on chutes and spillways. Other papers, equally practical, are to be found here and will be of aid to engineers who design chutes and tunnels.

This reviewer's principal problem with the volume is the lack of an overview. No framework is provided into which these papers may be fitted. Even the smaller groupings, which correspond to the sessions at which the papers were presented, leave a rather chaotic impression: How do these subjects fit together? It would seem that it is not enough to state a theme, such as the "frontiers of hydraulic engineering," designate an editor to review the format and other technical requirements, and then let matters take their course. Such an editor could not be expected to evaluate the technical quality of the work any more than a single reviewer could adequately evaluate all of the papers. Ideally, such conferences should be planned so that the convenor of each of the various sessions will be able to prepare an overview of the session which integrates the subject matter and highlights the technical points discussed in detail in the succeeding pages. For the actual sessions, more papers should be invited than will be used in the proceedings volume. Papers that do not fit the theme of the session should either be rejected or, if need be, the overview could be modified to incorporate them. Finally, in a brief review of so large a volume, this reviewer is left with the feeling that justice cannot be done. All the good papers cannot be listed, and the poor ones cannot be critiqued. All that can be accomplished is to give the reader a general impression of the volume and a few concrete examples of what the volume contains.

The book deserves a place in technical libraries. It is an excellent point of departure for research. The papers show the kinds of hydraulic research that are being done, including what is being modeled, although these models are not yet in general use. Moreover, the list of references accompanying each paper is a quick entrance into the field of interest.

Raphael G. Kazmann is a consulting engineer, Baton Rouge, La.

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Postdoctoral Fellowship in Geologic Remote Sensing. Start Fall 1984 for 12-month appointment — potentially renewable. We will be field testing a portable spectrometer (0.45–2.5 m) for use in quantify in the interpretation of multispectral remote images. The applicant should propose to make use of this capability in study problem(s) in geology, rock weathering, hydrothermal alteration, geobotany, petrology, etc. in the southwestern United States. Send vitae to: Professor Arden L. Albee, Division of Geological & Planetary Sciences, California Institute of Technology, Pasadena, CA 91125 or Dr. Alexander Goetz, Jet Propulsion Laboratory, MS 183-501, California Institute of Technology, Pasadena, CA 91109.

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Research Associate Position/University of Miami. The Division of Meteorology and Physical Oceanography, Rosenstiel School of Marine and Atmospheric Science, University of Miami, searches for a programmer/data analyst with several years of geophysical data analysis experience for processing and analysis of oceanographic data obtained by moored or shipboard instrumentation. Applicants should be experienced with FORTRAN and preferably also with the VAX-VMS system. Job duties may occasionally include participation in cruises. The successful applicant should have a Masters Degree in physical, mathematical or computer sciences. Application with curriculum vitae and names of three references should be sent to: Dr. Thomas N. Lee, Division of Meteorology and Physical Oceanography, Rosenstiel School of Marine and Atmospheric Science, 4600 Rickenbacker Causeway, Miami, Florida 33149, by 15 June 1984.

The University of Miami is a Private, Independent, International University and is an equal opportunity/affirmative action employer.

Chief of Telescope Operations/Haystack Observatory. Haystack Observatory has need for a Chief of Telescope Operations, who will be responsible for scheduling and coordinating astronomical observations using the Haystack 120-foot and 60-foot radio telescopes. The primary duties will be training and supervising telescope operators, scheduling antenna use for astronomy, maintenance, and other activities, and interfacing with investigators to assure the success of their observations. This person will also be the system manager of the HP1000 computers used to control the telescopes and data acquisition hardware; some experience in FORTRAN is required for maintenance of the existing software. In addition, participation in the evaluation of the feasibility and merit of proposals to use the telescopes for astronomical observations will be required; thus, the successful candidate is expected to have some knowledge of astronomy. Since successful observing depends on proper use of equipment, some experience with the use of instrumentation for scientific data collection is highly desirable. A negotiable fraction of time will be available for research and participation in software or instrumentation development, depending on the qualifications and interests of the applicant. We seek an individual with supervisory and organizational skills who is interested in a long-term commitment to furthering the progress of astronomical research. Haystack Observatory is operated by the Massachusetts Institute of Technology for the Northeast Radio Observatory Corporation, a consortium of Northeast institutions. It is located 40 miles northwest of Boston in a rural environment, with easy access both to city activities and to the coastline and mountains of New England.

Please write, enclosing resume to:

J. T. Karako
Assistant to the Director
Haystack Observatory
Westford, MA 01886.

MIT is an equal opportunity/affirmative action employer.

Hydrogeologists/Consulting. The Bethesda, MD, office of Dames & Moore has career opportunities available in our expanding hazardous waste management group. We are looking for individuals at the entry level or with 4 to 10 years experience with the following qualifications: 1) Minimum of a B.S. in geology or hydrogeology, 2) Design and review of groundwater sampling and monitoring programs, 3) Groundwater modeling, 4) Analysis of contaminant transport, 5) Field experience, 6) Excellent communications skills. Interested applicants should forward resumes to: Dames & Moore, 7101 Wisconsin Avenue, Suite 700, Bethesda, MD 20814, Attn: HG.

Dames & Moore is an equal opportunity employer.

Ocean Engineering Research/University of California, San Diego. The Institute of Marine Resources at the Scripps Institution of Oceanography, University of California, San Diego has three openings for assistant/associate research engineers or assistant/associate professors to participate in the development of ocean engineering programs. Candidates should have a Ph.D. or equivalent in engineering, physics or oceanography, a publication record and should have interest in taking part in research in one or more of the following fields: 1) deep ocean waves, remote and in situ measurement and analyses of directional spectra, and wave/structure interactions, 2) floating and fixed platforms, response to waves, structural analysis, corrosion and fatigue, 3) ocean floor geotechnical studies, initiation of mass movements, scour and soft bottom anchors. The salary range is $25,100-$35,300, depending upon qualifications. Appointment duration two years with possibility of indefinite extension. Appointment as professor is subject to the availability of an appropriate department billet. Appointment at the associate level requires a record of successful funded research. Associate professor rank requires teaching experience. Send resume and names of references before 1 September, 1984 to: F. N. Spiess, Director, Institute of Marine Resources, or R. J. Seymour, Head Ocean Engineering Research Group, Institute of Marine Resources, at Scripps Institution of Oceanography, La Jolla, CA 92093.

An equal opportunity, affirmative action employer.

Climate Research Institute/Research Assistant. Applications are invited for a position as Research Assistant which is expected to be available in the Climate Research Institute, Oregon State University, beginning in September 1984. This position involves research in climate modelling and the analysis of related data, and requires a basic familiarity with atmospheric dynamics, modelling and data analysis techniques. Salary within the range of $18,000—$20,000 will depend upon qualifications and experience. Interested candidates possessing the M.S. degree in atmospheric sciences and at least two years graduate-level experience are invited to submit an application with a summary of their university and research experience, and the names of two professional references, to Dr. W. L. Gates, Director, Climatic Research Institute, Oregon State University, Corvallis, OR 97331 before 15 July 1984.

Oregon State University is an Equal Opportunity/Affirmative Action Employer and complies with Section 504 of the Rehabilitation Act of 1973.

Research Observer/U.S. Department of Commerce. Position in South Pole, Antarctica. Conducts scientific measurements at the NOAA Baseline Observatory. Will make measurements of atmospheric CO_2, ozone, aerosols, other trace constituents, and meteorological parameters. This position is an electronics specialist (instrument). Responsibilities are calibration and maintenance of the Observatory instruments and data acquisition systems. We seek applicants with electronics technician background with at least 4 years of experience or electronics engineers with at least 2 years experience. The experience should be specialized in electronic instrumentation calibration and maintenance.

This position is a 15–24 month appointment. Duty station for the first 2 months will be in Boulder, Colorado for orientation and training, then at South Pole, Antarctica. NOAA will supply quarters, food, clothing at no cost during the tour of duty at the South Pole. The measurements supply information for current atmospheric research into climate and climate change. We offer an excellent salary (about $30,000—$40,000 per year, depending on qualifications and experience). For more information, contact Mr. Bernard Mendonca, U.S. Department of Commerce/NOAA, 325 Broadway, Boulder, Colorado 80303; telephone FTS 320-6733 or commercial (303) 497-6733.

NOAA is an equal opportunity employer.

Postdoctoral Position/UCLA. Postdoctoral position in experimental geochemistry/petrology available immediately for research on upper-mantle or lower-crustal problems. Successful applicant will have a strong background in thermodynamics and petrology. Send application to Art Boettcher, Institute of Geophysics and Planetary Physics, University of California, Los Angeles, California 90024, telephone (213) 825-8868.

UCLA is an equal opportunity/affirmative action employer.

Assistant Research Geophysicist. The Institute of Geophysics and Planetary Physics of the Ocean Research Division of the Scripps Institution of Oceanography are considering the appointment of an assistant research geophysicist, step 1 or 2, to join a research group conducting electromagnetic soundings of the ocean floor. Applicants should have experience with land and oceanic EM measurements, a demonstrated capacity to design and construct equipment, and the ability to carry out experiments at sea. A Ph.D. in geophysics or related sciences is required. Candidates should have some experience with the analysis and interpretation of EM data. Salary range is $25,100–$35,100. Applicants must submit a resume, copies of relevant publications, and the names of three references by 1 July 1984 to:

Dr. Alan Chave
University of California, San Diego
Institute of Geophysics and Planetary Physics
A-025
La Jolla, CA 92093.

The University of California is an affirmative action/equal opportunity employer.

Micropaleontologist/University of Puerto Rico, Mayaguez. Position open July 1, 1984. Assistant Professor level, tenure track, $17,820 per annum (9 months teaching). Ph.D. required. Duties will involve teaching at the graduate level courses in the discipline being considered here, supervising student research and conducting personal research.

Applicants should send curriculum vitae, a brief statement of teaching and research plans and three letters of recommendation to: Chairman, Appointments Committee, Department of Marine Sciences, University of Puerto Rico, Mayaguez, P.R. 00708. Telephone 809-832-4040, ext. 3443.

Research Position-Space Physics/Rice University. The Space Physics and Astronomy Department at Rice University seeks applicants for one or more full-time research positions within the department. Successful applicant(s) will play key role(s) in the development of theoretical three-dimensional models of the Earth's electromagnetic field. Applicants should have knowledge of, and interest in, at least one of the following areas: solar-wind magnetosphere interactions, magnetosphere-ionosphere coupling, ionosphere-atmosphere coupling, collisionless plasma microphysics, atmospheric electricity. Experience and/or interest in numerical modeling is an important consideration.

Title and salary level commensurate with experience, ranging from one-year Research Associateship (renewable in subsequent years depending on performance) to open-ended Research Scientist appointment in the Center for Space Physics. Please send resume and names of three professional references to T. W. Hill or R. A. Wolf, Space Physics and Astronomy Dept., Rice University, Houston, TX 77251.

The University is an equal opportunity/affirmative action employer.

University of Cambridge/Theoretical Seismologist. It is hoped soon to appoint a postdoctorate to work independently in the general field of theoretical seismology. An interest in seismic modelling and interpretation, particularly of body-waves, would be suitable. Stimulating environment with other theoretical, refraction, reflection and earthquake seismologists. University salary. Send curriculum vitae to Professor C.H. Chapman, Bullard Laboratories, Department of Earth Sciences, University of Cambridge, Madingley Road, Cambridge CB3 OEZ, England, by 31 July 1984.

Research Associate/Research Technician. The University of Maine at Orono (UMO) has an opening for a research associate/research technician who would work in a small geophysical group. We seek an individual who can use and maintain modern digital electronic equipment; for example, multichannel analysers, I/O interfaces for microcomputers, digital plotters and digitizing tablets. Familiarity with BASIC and FORTRAN will be needed, and some geophysical field work may be required as part of the duties of the appointee. Current funding permits an appointment for at least 12 months. Subject to arrival of anticipated funding, the appointment period could be extended to two years, or longer. Call Edward R. Decker at 207-581-2158 or 207-581-2152 about the position. Otherwise, send inquiries, a vita and a list of at least three references to Edward R. Decker, Department of Geological Sciences, 110 Boardman Hall, University of Maine at Orono, Orono, ME 04469.

The University of Maine is an equal opportunity/affirmative action employer.

Research Associate/Brown University. Research Associate in Planetary Geology at Brown University, Providence, Rhode Island. Experience in geologic/geomorphic analysis of planetary images, study of surface geologic processes, computerized image processing, and/or quantitative geomorphology is desirable. Deadline for applications is June 30, 1984. Submit resume, names and addresses of three references to Dr. James Head, Box 1846, Brown University, Providence, RI 02912.

Brown University is an equal opportunity affirmative action employer.

Postdoctoral Research Associate Positions/Geophysics and Igneous Geochemistry. The University of Maine at Orono (UMO) has postdoctoral openings for a solid earth geophysicist and an igneous geochemist. We seek a geophysicist who wishes to advance fundamental understanding of past and current thermal histories of the Appalachian Orogen in New England and elsewhere. The geochemist would be expected to investigate volcanic and plutonic suites in the Appalachians in Maine and in other terranes. Current funding permits appointments for at least 12 months. Subject to arrival of anticipated funding, the appointments could be extended to two years. Both appointments could start as early as August 1, 1984. Excellent facilities for geothermal research, computer applications, geologic research and geochronologic studies exist at UMO. Additionally, limited funds are available for travel and research, and the appointees will be encouraged to generate exterior support individually or through cooperation with existing faculty. Please send inquiries, a vita, a list of referees, and a description of research interests to Edward R. Decker or Daniel R. Lux, Department of Geological Sciences, 110 Boardman Hall, University of Maine at Orono, Orono, Maine 04469. Telephone calls may be made to 207-581-2152, and forwarded to Decker or Lux.

The University of Maine is an equal opportunity/affirmative action employer.

Assistant Professor of Geology. A one term, renewable (possible tenure track) position begins September 1, 1984. Ph.D. is required; needs strong background, interest in sedimentology. Will teach graduate/undergraduate courses in specialty and have strong interest in research. Salary commensurate with qualifications and experience. Review of credentials begins June 30, 1984. Send vita, statement of teaching and research interests and names of four references to: Search Committee, Department of Geology, Eastern Washington University, Cheney, WA 99004.

An equal opportunity employer.

Research Associate/University of Maryland. The Space Physics Group of the Department of Physics and Astronomy has an opening for a Research Associate beginning as early as July 1, 1984 for an initial one-year period with high likelihood of extension. The position involves research on energetic particles of solar and interplanetary origin. Applicants should possess a Ph.D. in a relevant area of physics or astrophysics; relevant research experience is highly desirable. Inquiries and applications should be addressed to Professor Glenn M. Mason, Department of Physics and Astronomy, University of Maryland, College Park, MD 20742. Applicants should send a vita including complete bibliography and a description of research experience, and should arrange for the sending of at least three letters of reference.

The University of Maryland is an equal opportunity/affirmative action employer.

Postdoctoral Fellow in Igneous Petrology. Available August 15, 1984, duration of 1–2 years. Areas of research include mineralogy/petrology/geochemistry of kimberlites and lunar rocks. A working knowledge of the electron microprobe is required. Please send resume, short summary of research goals and the names of three persons who may be contacted for recommendation to:

L.A. Taylor
University of Tennessee
Department of Geological Sciences
Knoxville, TN 37996
Telephone: 615-974-6015

Postdoctoral Research Positions in Planetary Atmospheres/Lunar and Planetary Laboratory, University of Arizona. Applications are invited for postdoctoral research positions at the Lunar and Planetary Laboratory, University of Arizona, in Tucson, Arizona. The two positions will involve research in planetary physics and analysis of UV data from the Voyager mission. Research opportunities for these positions include the bound and extended atmospheres and ionospheres of the giant planets and their satellites, the Io plasma torus, earth's atmosphere, the interstellar medium, and the atmosphere and ionosphere of Venus. Applicants should have a strong background in theory and data analysis. Physicists and astronomers are encouraged to apply. Curriculum Vita, bibliography and three letters of reference should be sent by July 15, 1984, to Dr. A. L. Broadfoot, Lunar and Planetary Laboratory, University of Arizona, 3625 E. Ajo Way, Tucson, Arizona 85713.

The University of Arizona is an Equal Opportunity Employer.

Electronics Engineer. Technical and supervisory position in new electronics facility in University of Arizona's Lunar & Planetary Laboratory. Design, construction, and maintenance of specialized scientific instruments and computer-based systems for laboratory, astronomical, and spacecraft applications. Minimum requirement of Bachelor's Degree and 5 years experience or equivalent. Experience with military or space-qualified hardware desirable.

Staff Employment Office
University of Arizona
1717 E. Speedway Blvd.
Tucson, AZ 85721.
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SERVICES, SUPPLIES, COURSES, AND ANNOUNCEMENTS

STUDENT OPPORTUNITIES

Special Doctoral Research Assistantships. The Department of Oceanography of Old Dominion University has several special doctoral research assistantships available for Fall Semester, 1984 and 1985. These carry a stipend of $7,000 per academic year, renewable for three years. Applicants with M.S. degrees qualify for waiver of tuition. Students interested in obtaining the Ph.D. in the areas of biological, chemical, geological, or physical oceanography should send an introductory resume to Dr. Ronald E. Johnson, Graduate Program Director, Department of Oceanography, Old Dominion University, Norfolk, VA 23508.

Old Dominion University is an affirmative action/equal opportunity institution.

Meetings

Announcements

Water Quality Modeling

September 6–7, 1984 Conference on Stormwater and Water Quality Management Modeling, Hamilton, Ontario, Canada. (William James, Civil Engineering Department, McMaster University, Hamilton, Ontario, Canada, L8S 4L7.)

The deadline for *submitting* abstracts is July 1, 1984.

Conference talks will concern modeling pollution from urban and industrial sources. Papers are particularly solicited on emerging microcomputer hardware and software techniques in stormwater, flood, and pollution management.

Tar Sand Symposium

June 26–29, 1984 WRI-DOE Tar Sand Symposium, Vail, Colo. Sponsors: Western Research Institute, U.S. Department of Energy. (L. C. Marchant, Western Research Institute, P.O. Box 3395, University Station, Laramie, WY 82071; tel.: 307-721-2203.)

Technical sessions will run from June 27–29, with informal technical discussions planned for June 28. Among the topics addressed by formal speakers will be resources, in situ extraction processes, bitumen properties and upgrading, mining and plant extraction processes, and environmental and economic concerns.

Environmental Data Users

August 19–22, 1984 Pathways and Future Directions for Environmental Data and Information Users, Denver, Colo. Sponsor: NOAA. (SES, Incorporated, P.O. Box 2697, Springfield, VA 22152.)

Early registration deadline is July 1, 1984.

The objective of the conference is to increase user awareness of the range of environmental data available to the public. The program will consist of panel presentations followed by question and answer periods. The use of environmental data in many disciplines will be addressed, including legal and insurance industries, travel and recreation industries, communications and aerospace industries, urban and regional planning, renewable resources management, health and natural hazard monitoring, architecture and engineering, and marine exploration and coastal zone development. There will also be exhibits and displays from each of the four data centers of the National Environmental Satellite, Data, and Information Service.

Magnetism and Magnetic Materials

November 27–30, 1984 Thirtieth Annual Conference on Magnetism and Magnetic Materials, San Diego, Calif. Sponsors: American Institute of Physics, Magnetics Society of IEEE. (John Scott, American Institute of Physics, 335 East 45th St., New York, NY 10017.)

The deadline for submitting abstracts is July 6, 1984.

The purpose of the conference is to bring together scientists and engineers interested in recent developments in all branches of fundamental and applied magnetism. Emphasis is placed on *experimental* and *theoretical* research in magnetism, the properties and synthesis of new magnetic materials, and advances in magnetic technology. The program will consist of both invited and contributed papers.

Meeting Report

Yosemite Conference

A conference on Planetary Plasma Environments: A Comparative View was held in Yosemite, Calif., January 30 to February 3, 1984. The purpose of the conference was to discuss the comparative aspects of planetary and cometary plasma systems. Major support for the conference was provided by the National Aeronautics and Space Administration, Office of Space Science and Applications. Additional sponsorship was provided by Ball Aerospace Systems Division, TRW Space and Technology Group, the American Geophysical Union, and Stanford University.

Over the last 10 years, we have obtained important new information on the planetary plasma environments of Venus, Jupiter, and Saturn. In addition, there are several planned cometary flyby and rendezvous missions which will be taking a first in situ look at these interesting objects in the next 5 years. This, coupled with the increased exploration and understanding of the earth's system (particularly the study of magnetosphere-ionosphere coupling, which has been the subject of several past Yosemite meetings), made the topic of comparative planetary plasma environments an excellent choice for the fifth biennial Yosemite topical conference.

The program was organized into five main sessions. The opening session provided an overview of the major morphological features of planetary and cometary systems. The following two sessions discussed the plasma and energy sources that operate in these systems. These early sessions provided the framework for the final two sessions, which dealt with the interaction of the various plasma components of the systems and with the commonality of the physical processes that take place within the solar system environments.

Chris Russell of the University of California, Los Angeles began the first session with a whirlwind tour discussing the solar wind interactions with various inner solar system bodies. The outer planets were then addressed by Ralph McNutt of the Massachusetts Institute of Technology, and Tom Cravens of the University of Michigan discussed the interaction of comets with the solar wind.

The first session identified several interesting questions that were explored in subsequent sessions of the conference. (1) What is the nature of the solar wind interaction with Mars? (2) How important is the role of ionospheric plasma as a source of magnetospheric plasma at the outer planets? (3) What is the difference between the solar wind/comet and the solar wind/Venus interactions? These questions not only stimulated much discussion throughout the conference, but also suggested future planetary missions and instrumentation that could help address these questions.

The second session focused on sources of plasma within planetary and cometary systems. Doug Torr discussed the role of both electron precipitation and solar EUV production of ionospheric plasma with emphasis on the need for proper calibration of the existing solar EUV data sets. He indicated that in regions of the EUV spectrum there may be as much as a factor of 3 error in the widely used Hinteregger EUV fluxes and that proper calibration can help to explain the long standing discrepancy between the modeled and measured photoelectron spectrum.

Tamas Gombosi contrasted and compared the structure of the Venusian, Martian, and terrestrial ionospheres. While O^+ is the major ion in the upper ionosphere for all these planets, the minor ion composition is weighted toward nitrogen-derived ions for earth and carbon dioxide–derived ions for Venus and Mars. It was also noted that the maintenance of the nighttime Venusian ionosphere is due mainly to ion flows from the dayside driven by plasma pressure gradients, rather than particle precipitation as first suspected from early Soviet Venera Data.

The ionospheric structure in the outer planets was reviewed by Sushil Atreya. He indicated that in the high latitude ionospheres of Jupiter, Saturn, and Uranus the auroral precipitation energy is large enough to provide the dominant source of ionization but that at low and mid-latitudes, solar EUV sources were thought to dominate.

Asoka Mendis identified four possible sources of ions for cometary systems: (1) photoionization, (2) charge exchange with solar wind ions, (3) electron impact ionization, and (4) critical velocity ionization. He reviewed both chemical and dynamical modeling of comets, noting some of the controversial ideas that have developed from these models. These ideas fueled the discussion that followed the talk. The discussion centered on the role of friction, between the dust and the escaping gas in a cometary system, as a means of providing a choke for a transonic gas expansion in the cometary atmosphere.

The solar wind as a source of ionization in magnetospheric systems was discussed by Tim Eastman. Tim estimated that about 7×10^{26} ions s^{-1} enter the frontside magnetosphere from the solar wind. He suggested that in quiet times the solar wind source dominated the plasma sheet composition, yet in storm times the earth's ionosphere became the dominant source of plasmasheet plasma. He suggested that effusive processes associated with wave particle interactions is a major process for solar wind plasma entry to the earth's magnetosphere and that magnetic merging is less significant. Tom Hill disagreed with this point of view during the discussion period, suggesting that the relative importance of the two processes is still an open question.

Critical velocity ionization was discussed by Patrick Newell of the University of California, San Diego. Although Titan, Io, and comets have been suggested as locations where this effect might be an important source of ionization, very little experimental evidence for critical velocity ionization in space plasmas exists at this time. Peter Banks, nevertheless, suggested that this mechanism might be responsible for the high ion densities (5×10^5 cm^{-3}) seen around the space shuttle during dayside orbital segments on *STS-3*.

The energy sources session next focused attention on the energization of plasmas in planetary systems. Bill Knudson began the session by discussing plasma energization at the inner planets with particular emphasis on Venus using Pioneer Venus measurements. He indicated that as one crosses from the solar wind through the mantle interaction region to the Venusian ionosphere, the electron temperature goes from 10 to 100 eV due to ion exchange with the solar wind. Waves are also produced by the solar wind interaction that, through Landau damping, serve as a heat source for the topside ionosphere. Knudson estimated that about 5% of the solar wind energy incident on Venus comes into the ionosphere.

This behavior of a fairly direct energization of the planetary plasma at Venus was contrasted with more complex solar wind/magnetosphere energization processes in a review by Michael Schulz. The observed monotonic decrease of energetic phase space density with decreasing L indicates that the plasma energization in the earth's magnetosphere is intrinsic to the inward transport driven by solar wind/magnetospheric convection.

Alex Dessler gave an interesting talk, suggesting that planetary rotation, by exerting a magnetic torque, may be a general source of energy for magnetosphere systems. He indicated that there are two ways to supply the torque: (1) to have an internal plasma source such as Io in the Jovian system or (2) to have an external plasma source such as the solar wind. Alex and coworkers have done some recent calculations, indicating that this may be an important source of energy for the magnetospheres of Jupiter, Saturn, Uranus, and possibly Neptune.

In the absence of collisions within planetary plasma systems, waves provide the required dissipation and thus serve as important means of redistributing energy within the system. Maha Ashour-Abdalla suggested that there are two types of wave heating: (1) quasi-linear heating by many low amplitude wave modes, or (2) heating by a few strong wave modes where particle orbits that were originally bounded become unbounded and stochastic. The remainder of her presentation dealt with a specific example of the latter process.

While the first three sessions dealt with the separate elements of planetary and cometary plasma systems, the fourth session (interactive plasma processes) addressed the interplay between the separate components. The session began with a presentation of some examples of terrestrial magnetosphere-ionosphere coupling processes.

Hunter Waite reviewed recent results from the Dynamics Explorer satellite program. These included recent studies on ion-neutral coupling processes and also DE 1 observations of low-energy ion outflows observed at high latitudes in the terrestrial magnetosphere. In particular, significant fluxes of O^+ are commonly observed flowing out of the ionosphere at high altitudes over the polar cap.

A review of terrestrial ionosphere-magnetosphere modeling was given by Dick Wolf. Carl McIlwain questioned the substorm scenario and suggested that the magnetic field configuration might simply set up the electric field that then led to auroral precipitation. Carl McIlwain and Peter Banks both asked if it was possible that mass loading of the high latitude magnetosphere was an important consideration for the convection electric field, a question certainly inspired from earlier presentations on mass loading of the solar wind at Venus and in comet systems.

Janet Luhmann presented results on the Venus–solar wind interaction. She indicated that there is a conversion of solar wind dynamic pressure to magnetic pressure that is matched by the ionospheric pressure at the ionopause. The solar wind dynamic pressure controls the altitude of the ionopause. When the altitude approaches its minimum observed value of 200 km, large-scale magnetic fields develop within the ionosphere. These fields, according to Luhmann, can be explained as a result of a combination of vertical convection of magnetic flux from the ionopause and diffusion. Rob Wolfe, however, asserted that the Cloutier model of the interaction does not agree with this interpretation. In the Cloutier model, a large-scale current system is driven in the ionosphere by absorption of solar wind plasma. A long discussion on the virtues of both model ensued, and it was clear that more careful study will be required to determine which physical scenario produces the correct magnetic field within the Venus ionosphere.

The emphasis then switched to the outer planets and the interesting new results that show the importance of moons and rings as sources and sinks of magnetospheric plasma. Chris Goertz categorized the effects of moons by whether they had an atmosphere and whether they were magnetized or not.

The interaction of comets with the solar wind was revisited by W. H. Ip. Again, the contrast of the cometary case with the Venus interaction focused on the greater degree of mass loading ahead of the shock and possible strong wave particle interactions that could lead to the formation of a weak cometary bow shock. Ip also suggested that the wavy or kinky configurations observed in cometary ion tails are indicative of Kelvin-Helmholtz or Rayleigh-Taylor instabilities triggered by solar wind disturbances. In addition, Rick Elphic presented some evidence of filamentary structures in the Venus nightside ionotails that are quite suggestive of comet ion tails and may serve as further evidence of similar physical processes in the Venus and cometary/solar wind interactions.

The final session attempted to identify and describe some of the common plasma processes that occur in solar system plasmas. Ron Lepping began the session with a talk on bow shock and magnetopause formation. All planets observed to date have a bow shock and all but Venus have a magnetopause. The characteristics of the bow shocks of planets depend strongly on the solar wind conditions, whereas the shape of a magnetopause will depend crucially on the detailed three-dimensional pressure profile it presents to the solar wind.

Acceleration processes in plasma systems appear to be an important common process as deomonstrated by the observation of auroras at Earth, Jupiter, Saturn, and Uranus. Tom Hill opened his talk on the subject by indicating that acceleration of particles in a magnetosphere implied the violation of the rules of MHD. He classified these processes according to the invariant violated and showed that his was self-consistent with classifying acceleration processes according to their timescales or their physical mechanism. He concluded by pointing out three new challenging questions for future contemplation: (1) What produces energetic particle bursts? (2) Why does the Io plasma torus heat as it moves radially outward from Jupiter? (3) Why is O^+ accelerated in the terrestrial polar cap?

Transport processes within plasma systems were reviewed by George Siscoe. Charged particles move through magnetospheres in three ways: (1) convection, (2) diffusion, and (3) field-aligned winds. Charge exchange, however, also causes mass transport by converting magnetically bound ions into fast unbound neutrals. Steady and nonsteady convection is driven in the earth's magnetosphere by merging between the planetary magnetic field and the solar wind magnetic field. This is to be contrasted with the magnetosphere of Jupiter, where convection may be driven by centrifugal force acting on an inhomogeneous distribution of corotating plasma. Siscoe also noted that when induced electric fields are present, as must be the case during magnetic field collapse or inflation, magnetospheric motions are not necessarily reflected in ionospheric motions. Nonsteady magnetic merging can also generate plasma bubbles (plasmoids) which are a source of field-aligned winds. Diffusion is needed to account for particles with energies higher than the convection potential and is important in the earth's radiation belts and possibly in Jupiter's middle magnetosphere. Transport processes can also be driven by atmospheric circulation. Indeed, in a magnetosphere, stresses on both ends of a magnetic field line must be balanced and communicated by means of field-aligned currents.

Meetings *(cont. on p. 386)*

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(over)

Meetings (cont. from p. 385)

The coupling between the upper atmosphere and magnetosphere was further addressed by Ray Roble. He used as an illustrative example the terrestrial case where both solar EUV heating and ion-neutral coupling produce strong forcing on the high latitude upper atmosphere. Although separate numerical models of global electrodynamics, ionospheric dynamics, and thermospheric dynamics for the earth now exist, the next major step in understanding this interaction is to couple these models together. This work is now in progress. It was also pointed out by several people at the conference that the large auroral energy inputs at Jupiter, Saturn, and Uranus would also result in complex coupling between the magnetosphere and upper atmosphere, as is the case at earth.

The energetics of planetary plasmas was addressed by Larry Brace. He used as contrasting examples the ionospheres of Earth and Venus. Both planetary ionospheres are heated by photoelectrons and by wave-particle interactions generated at important plasma boundaries (e.g., the plasmapause at Earth and the ionopause at Venus). Larry also mentioned the observation of electron temperatures of greater than 10,000 K in the terrestrial dayside auroral zone and cusp, which may help to explain the presence of low-energy O^+ ion outflows observed over the polar cap on the DE spacecraft. The elevated electron temperature may increase the ambipolar electric field enough to enable O^+ to overcome the gravitational barrier and escape.

Sources and losses of plasma were collectively dealt with by Peter Banks on the ionosphere as a source of magnetospheric plasma and by Andy Cheng on rings and moons as plasma sources. Peter covered the evolution of our ideas on the source of plasma in the earth's magnetosphere. While in the 1950's all plasma was thought to come from the solar wind, recent DE measurements now suggest a plethora of low-energy H^+, He^+, and O^+ ions coming out of the earth's high latitude ionosphere. He suggested that this could cause us to reexamine some of our theoretical understanding of polar wind processes.

In outer planet magnetospheres, the present emphasis is understandably on the relatively new phenomenon of moons as a source of magnetospheric plasma. Cheng indicated that source mechanisms for particle escape from the moons included sputtering, sublimation, thermal escape, and ion pickup. Neutrals can escape before they are ionized. Satellites and rings can also lead to a loss of plasma. These loss processes include satellite sweeping, absorption, and wave-particle interactions.

Richard Thorne gave a theoretical review of wave processes in planetary magnetospheres. He began by stating that waves dominate magnetospheric dynamics by (1) providing rapid loss of energetic particles, (2) relaxing unstable distributions, and (3) providing energy equipartition. He went on to clarify that in magnetospheres, transport dominates in the outer magnetosphere and loss rates from wave processes dominate in the inner magnetosphere. Lou Lanzerotti still felt this to be an oversimplification. He stated in a comical, yet serious, fashion that waves dominate everywhere, except where there are exceptions, such as (1) particle collisions in cold, dense tori; (2) rings; (3) satellites; and (4) dust.

Thus, the conference ended as it began, in debate and good scientific exchange. The conference, by being broad in scope, not only provided each scientist an opportunity to look at the overall picture and actually become involved in comparative magnetospheric physics, but also assured that no one could be an expert on everything. All attendees left knowing more than they did when they arrived.

More specifically, the conference indicated the need to carry out some cometary missions to take advantage of the vast amount of information on the Venus-solar wind interaction collected by Pioneer Venus. The conference indicated the need to fly an ionosphere-magnetosphere mission to Mars to understand the nature of the solar wind interaction with that planet. The conference also suggested that further measurements of the dynamical motions and the ion outflows (over the thermal to MeV energy range) from the high latitude ionospheres and thermospheres of the outer planets would contribute greatly to our study of magnetosphere-ionosphere coupling processes. On a more practical note, suggestions were made to (1) do a careful comparison between Cloutier's model and other models of the Venus solar wind interaction, (2) complete reduction of the lower ionosphere data of the Jupiter and Saturn ionospheres because these measurements are important in determining the ionospheric conductivities and thus the degree of coupling between the ionospheres and magnetospheres in these systems, and (3) move forward with coupled chemical and dynamical models of cometary and planetary systems.

This meeting report was contributed by J. H. Waite, Marshall Space Flight Center, Huntsville, Ala., and C. R. Claver, STAR Laboratory, Stanford University, Standford, Calif.

Geophysical Year

A date at the end of an entry indicates the issue of *Eos* in which a full meeting announcement was run.

A list of abbreviations used in the Geophysical Year calendar appears at the end of the calendar.

Future AGU Meetings

Fall Meetings

Dec. 3–7, 1984, San Francisco
(Abstracts due mid-September 1984)

Dec. 9–13, 1985, San Francisco
(Abstracts due mid-September 1985)

Spring Meetings

May 27–31, 1985, Baltimore
(Abstracts due early March 1985)

Chapman Conferences

The Magnetospheric Polar Cap
August 6–9, 1984, Fairbanks

Vertical Crustal Motion: Measurement and Modeling
October 22–26, 1984, Harpers Ferry, W. Va.
(Abstracts due August 1, 1984)

1984

June 4–6 International Conference on Inverse Problems of Acoustic and Elastic Waves, Ithaca, N. Y. Sponsor: Cornell University. (Yih-Hsing Pao, Department of Theoretical and Applied Mechanics, Cornell University, Ithaca, NY 14853; tel.: 607-256-2345.)

June 4–7 Symposium on Climate and Paleoclimate of Lakes, Rivers, and Glaciers, Igls, Austria. Sponsor: International Commission on Climate, IAMAP. (M. Kuhn, Institut fur Meteorologie und Geophysik, Schoepfstrasse 41, A-6020 Innsbruck, Austria.) (Oct. 25, 1983.)

June 4–8 IWRA Seminar on River Basin Strategy, Linköping, Sweden. (U. Lohm, Water Theme, Linköping Univ., S-58183, Linköping, Sweden.) (Oct. 18, 1983.)

June 4–8 Seventh International Conference on Atmospheric Electricity, Albany, N. Y. Sponsors: IAMAP International Commission on Atmospheric Electricity, AMS, and AGU. (R. E. Orville, Atmospheric Electricity Conference, E.S. 214, 1400 Washington Ave., SUNY, Albany, NY 12222; tel.: 518-457-3987.) (July 26, 1983.)

June 4–8 Third International Conference on Urban Storm Drainage, Göteborg, Sweden. Sponsors: IAHR and International Association on Water Pollution Research. (P. Malmqvist, c/o Dept. of Hydraulics, Chalmers Univ. of Technology, S-412 96 Göteborg, Sweden.)

June 5–6 Ogallala Symposium II, Lubbock, Tex. Sponsors: Texas Tech University Water Resources Center, International Center for Arid and Semi-Arid Land Studies, High Plains Underground Water Conservation District No. 1, Panhandle Underground Water Conservation District, Oklahoma State Univ. Div. of Agriculture, USGS. (WRC, Texas Tech. Univ., Lubbock, TX 79409; tel.: 806-742-3597.) (May 1, 1984.)

June 6–9 Second American Conference on Ice Nucleating Bacteria, Flagstaff, Ariz. (Ralph M. Bilby Research Center, Box 6013, Northern Arizona Univ., Flagstaff, AZ 86011.) (Nov. 15, 1983.)

June 10–12 Canadian Hydrology Symposium 1984, Quebec, Canada. Sponsor: National Research Council of Canada Associate Committee on Hydrology. (H. R. Whiteley, School of Engineering, Univ. of Guelph, Guelph, Ontario N1G 2W1.) (May 1, 1984.)

June 10–15 65th Annual Meeting of the American Association for the Advancement of Science (Pacific Division), San Francisco, Calif. (John H. Vann, Dept. of Geography, California State Univ., Hayward, CA 94542; tel.: 415-881-3193.) (Jan. 31, 1984.)

June 11–12 Fifth European Conference on Environmental Pollution, Amsterdam, The Netherlands. (V. M. Bhatnager, Box 1779, Cornwall, Ontario K6H 5V7, Canada.)

June 11–13 Symposium on Critical Assessment of Forecasting in Western Water Resource Management, Seattle, Wash. Sponsors: AWRA and AGU. (G. R. Minton, President, Resource Planning Assoc., 113 Lynn St., Seattle, WA 98109; tel.: 206-282-1681.) (May 15, 1984.)

June 11–13 American Astronomical Society Meeting, Baltimore, Md. (Richard C. Henry, Physics Dept., Johns Hopkins Univ., Baltimore, MD 21218.)

June 11–15 International Conference on Agriculture and Environment, Venice, Italy. Organizers: Aldo Giorgini, Purdue Univ.; Franco Zingales, Univ. of Padua. (Aldo Giorgini, School of Civil Engineering, Purdue Univ., West Lafayette, IN 47907; tel.: 317-494-2173.)

June 14–15 Conference on Delineation of Landslide, Flash Flood, and Debris Flow Hazards in Utah, Logan, Utah. Sponsors: Utah Water Research Laboratory, Utah State Univ., Utah Geological and Mineral Survey, National Research Council Committee on Natural Disasters, and Utah Science and Technology Council. (David Bowles, Utah Water Research Laboratory, Utah State Univ., UMC 82, Logan, UT 84322.) (May 8, 1984.)

June 17–23 Second International Tsunami Conference, Las Vegas, Nev. (Tsunami Society, Box 8523, Honolulu, HI 96815.)

June 18–22 Fifth International Conference on Finite Elements in Water Resources, Burlington, Vt. Sponsors: Univ. of Vermont, AGU. (J. P. Laible, Dept. of Civil Engineering and Mechanical Engineering, Univ. of Vermont, Burlington, VT 05405; tel.: 802-656-3800.) (May 29, 1984.)

June 19–21 Third International Conference on Marine Simulation, Rotterdam, The Netherlands. Sponsor: Maritime Research Institute Netherlands. (Secretariat MARSIM 84, c/o Maritime Research Institute Netherlands, P.O. Box 1555, 3000 BN Rotterdam, The Netherlands.)

June 20–22 Indiana Water Resources Association Fifth Annual Symposium, Bloomington, Ind. Sponsors: Indiana Water Resources Association, AGU, ASCE (Indiana Section). (Jeffrey Martin, U.S. Geological Survey, 6023 N. Guion Rd., Suite 201, Indianapolis, IN 46254; tel.: 317-927-8640.) (May 29, 1984.)

June 22–26 Practical Applications of Groundwater Geochemistry, Banff, Alberta, Canada. Sponsors: the Alberta Research Council and the National Water Well Association. (David Nielsen, NWWA, 500 W. Wilson Bridge Road, Worthington, OH 43085.) (April 24, 1984.)

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MEMBER JOURNAL SUBSCRIPTION RATES – 1984

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June 23–30 Penrose Conference on Melanges of the Appalachian Orogen, Newfoundland, Canada. Sponsor: GSA. (Brenna E. Lorenz, Dept. of Earth Sciences, Memorial Univ. of Newfoundland, St. Johns, Newfoundland A1B 3X5 Canada.) (June 28, 1983.)

June 24 International Conference on Geomembranes, Denver, Colo. (A. I. Johnson, Woodward-Clyde Consultants, 7600 E. Orchard Rd., Englewood, CO 80111; tel.: 303-694-2770.)

June 24 International Symposium on Impermeable Barriers for Soil and Rock, Denver, Colo. (A. I. Johnson, Woodward-Clyde Consultants, 7600 E. Orchard Rd., Englewood, CO 80111; tel.: 303-694-2770.)

June 24–30 14th International Conference on Mathematical Geophysics, Loen, Norway. (L. Tronrud, NTNF/NORSAR, P.O. Box 51, N-2007 Kjeller, Norway; telex: 18147 kcin.)

June 25–27 Technology Transfer Society Ninth Annual Meeting and International Symposium, Boston, Mass. (Margaret McNamara or Jack Griffin, Naval Underwater Systems Center, New London, CT 06320; tel.: 203-440-4590 or -4116.)

June 25–27 Rock Mechanics in Protection and Productivity, 25th U.S. Symposium on Rock Mechanics, Evanston, Ill. Sponsor: AGU. (Charles H. Dowding, Dept. of Civil Engineering, Northwestern Univ., Evanston, IL 60201; tel.: 312-492-7270.) (Sept. 13, 1983.)

June 25–29 Gordon Research Conference on Environmental Sciences: Water Interfacial Processes, New Hampton, N. H. (Alexander M. Cruickshank, Director, Gordon Research Conferences, Univ. of Rhode Island, Kingston, RI 02881–0801; tel.: 401-783-4011 or 401-783-3372.) (April 17, 1984.)

June 25–29 Gordon Research Conference on Research at High Pressure, Meriden, N. H. (Alexander M. Cruickshank, Director, Gordon Research Conferences, Univ. of Rhode Island, Kingston, RI 02881–0801; tel.: 401-783-4011 or 401-783-3372.) (April 17, 1984.)

June 25–July 7 ICSU Committee on Space Research 25th Meeting, Graz, Austria. (Richard C. Hart, Space Science Board, JH-828, National Academy of Sciences, 2101 Constitution Ave., N.W., Washington, DC 20418.)

June 25-July 7 Symposium on Space Observations for Climate Studies, Graz, Austria. Sponsor: World Climate Program. (S. Ruttenberg, Secretary, COSPAR Commission A, NCAR, Boulder, CO 80307.) (July 19, 1983.)

June 26–28 Symposium of the Achievements of the International Magnetospheric Study, Graz, Austria. Sponsor: ICSU Scientific Committee on Solar-Terrestrial Physics. (J. G. Roederer, Geophysical Institute, Univ. of Alaska, Fairbanks, AK 99701.)

June 26–28 1984 International Conference on Lightning and Static Electricity, Orlando, Fla. Sponsors: NOAA, IEEE, SAE-AE4 Committee, and several military and civilian air transportation agencies in the U.S. and UK. (J. J. Fisher, Conference Chairman, U.S. Naval Air Systems Command, P.O. Box 15036, Arlington, VA 22215; tel.: 202-692-7822; or G. Odam, European Coordinator, Royal Aircraft Establishment, Farnborough, Hants, GU14 5TD UK; tel.: 0252–24461, ext. 2638.) (Sept. 6, 1983)

June 26–28 *International Symposium on Deep* Structure of the Continental Crust: Results from Reflection Seismology, Ithaca, N.Y. Sponsors: Cornell Univ. Institute for the Study of the Continents, AGU, GSA, IASPEI, International Lithosphere Program, SEG. (Muawia Barazangi, Conference Coordinator, Dept. of Geological Sciences, Cornell Univ., Ithaca, NY 14853; tel.: 607-256-6411 or telex: 937478.)

June 26–29 WRI-DOE Tar Sand Symposium, Vail, Colo. Sponsors: Western Research Institute, U. S. Department of Energy. (L. C. Marchant, Western Research Institute, P.O. Box 3395, University Station, Laramie, WY 82071; tel.: 307-721-2203.) (June 5, 1984.)

July 2–5 Symposium on the Physics of the Magnetosphere-Ionosphere Connection, Graz, Austria. Sponsor: Commission on Space Research of ICSU. (E. R. Schmerling, EE-8, NASA Headquarters, Washington, DC 20546.) (Dec. 6, 1983.)

July 3–6 Second Symposium on Plasma Double Layers and Related Topics, Innsbruck, Austria. (R. Schrittwieser, Inst. for Theoretical Physics, Univ. of Innsbruck, Sillgasse 8, A-6020 Innsbruck, Austria.)

July 9–13 International Symposium on Space Techniques for Geodynamics, Sopron, Hungary. Sponsors: Hungarian Academy of Sciences and IAG/COSPAR Joint Commission on the International Coordination of Space Techniques for Geodesy and Geodynamics. (Ch. Reigber, Deutsches Geodätisches Forschungsinstitut, Abt. I, Marstallplatz 8, D-8000 Munich 22, FRG.)

July 9–13 Longitude Zero, Greenwich, UK. Sponsors: International Union for the History and Philosophy of Science and the International Astronomical Union. (Conference Officer, "Longitude Zero" Symposium, National Maritime Museum, Greenwich, London SE10 9NF, UK.) (Nov. 15, 1983.)

July 10–14 The Case for Mars II, Boulder, Colo. Sponsors: Mars Institute of the Planetary Society. (Helen Hart, Laboratory for Atmospheric and Space Physics, Univ. of Colorado, Boulder, CO 80309; tel.: 303-492-8822; Carol Stoker or Tom Meyer, Case for Mars, P.O. Box 4877, Boulder, CO 80306; tel.: 303-494-8144.) (Dec. 20, 1983.)

July 18–20 Seismic Deconvolution Workshop, Vail, Colo. Sponsor: SEG. (Sven Treitel, Amoco Production Co., Research Center, P.O. Box 591, Tulsa, OK 74102.) (Feb. 7, 1984.)

July 19–25 Symposium on Wave Breaking, Turbulent Mixing, and Radio Probing of the Ocean Surface, Sendai, Japan. (O. M. Phillips, Dept. of Earth and Planetary Sciences, Johns Hopkins Univ., Baltimore, MD 21218; tel.: 301-338-7036.)

July 21–28 Eighth World Conference on Earthquake Engineering, San Francisco. Sponsor: Earthquake Engineering Research Institute. (Dr. Penzien, Earthquake Engineering Research Institute, 2620 Telegraph Ave., Berkeley, CA 94704; tel.: 415-848-0972.)

July 23–24 Eastern Regional Groundwater Conference, Newton, Mass. Sponsor: National Water Well Association Technology Division. (Alice Vickerman, National Water Well Association, 500 W. Wilson Bridge Rd., Worthington, OH 43085; tel.: 614-846-9355.)

July 23–25 Summer Computer Simulation Conference, Boston, Mass. Sponsor: Society for Computer Simulation. (W. D. Wade, 1984 SCSC Program Chairman, Wade Engineering P.C., P.O. Box 849, Huntington, NY 11743; tel.: 516-271-6075.)

July 23–26 11th International Symposium on Urban Hydrology, Hydraulics, and Sediment Control, Lexington, Ky. Sponsor: Univ. of Kentucky. (Dr. Haden, Coordinator, Office of Continuing Education/Engineering, 223 Transportation Research Bldg., Univ. of Kentucky, Lexington, KY 40506-0043; tel.: 606-257-3972.) (Nov. 15, 1983.)

July 23–27 International Symposium on Challenges in African Hydrology and Water Resources, Harare, Zimbabwe. Sponsors: IAHS, UNESCO, WMO. (Zimbabwe Conference Board, P.O. Box A585 Avondale, Harare, Zimbabwe; tel.: 308222; telex: 4-283 ZW.)

July 24–26 Water Rights Specialty Conference, Flagstaff, Ariz. Sponsors: Ground Water Committee and Surface Water Committee of the ASCE Irrigation and Drainage Division. (Kenneth G. Renard, Southwest Watershed Research Center, 2000 E. Allen Rd., Tucson, AZ 85719; tel.: 602-629-6381.)

July 26–27 A Joint Workshop of the Committee on Climatic Changes and the Ocean and the Joint Scientific Committee for World Climate Research Panel, Sendai, Japan. (O. M. Phillips, Dept. Earth and Planetary Sciences, Johns Hopkins Univ., Baltimore, MD 21218; tel.: 301-338-7036.)

July 29–31 Conference on Educational Prerequisites for Water Resources Management, Baton Rouge, La. Sponsor: Universities Council on Water Resources. (Yacov Haimes, Chairman, Systems Engineering Dept., Case Institute of Technology, Case Western Reserve Univ., Cleveland, OH 44106; tel.: 216-368-4492.)

July 30–August 2 Seminar on Water Management Practice, Zaria, Nigeria. Sponsors: International Association for Hydraulic Research and UNESCO. (Gunnar Lindh, Dept. of Water Resources Engineering, Lund Institute of Tech., Fack 725, S-220 07 Lund, Sweden.) (Dec. 6, 1983.)

July 30–August 3 Eurogeophysics Assembly, Louvain-la-Neuve, Belgium. Sponsor: European Geophysical Society. (D. M. Brown, Dept. of Physics, Univ. College of Wales, Aberystwyth, Wales, UK.) (Dec. 20, 1983.)

July 31–Aug. 2 Fourth International Symposium on Stochastic Hydraulics, Univ. of Illinois, Urbana-Champaign. Sponsors: IAHR and AGU. (Ben C. Yen, Wilson H. Tang, or Glenn E. Stout, Dept. of Civil Eng., Univ. of Illinois, 208 N. Romine St., Urbana, IL 61801; tel.: 217-333-0687 or 333-0536.) (Nov. 8, 1983.)

July 31–August 3 Workshop on Fission Track Dating, Troy, N. Y. Sponsors: General Electric R&D Lab., SUNY at Albany, and Rensselaer Polytechnic Institute. (Donald S. Miller, Dept of Geology, Rensselaer Polytechnic Institute, Troy, NY 12181.)

Aug. 4–14 27th International Geological Congress, Moscow, USSR. Sponsor: USSR National Committee for Geology, IUGS. (Organizing Committee of the 27th IGC, Institute of the Lithosphere, 22, Staromonetny, Moscow, 109180, USSR.)

Aug. 6–9 Chapman Conference on the Magnetospheric Polar Cap, Fairbanks, Alaska. (Polar Cap Meeting, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.) (Jan. 24, 1984.)

Aug. 12–17 20th Annual AWRA Conference and Symposium, Washington, D. C. (Arlene Dietz, U.S. Army Corps of Engineers, Institute for Water Resources, Casey Bldg., Fort Belvoir, VA 22060; tel.: 703-355-2368.) (Aug. 16, 1983.)

Aug. 13–17 Gordon Research Conference on Chemical Oceanography, Meriden, N. H. Chairman: William Sackett. (Alexander M. Cruickshank, Director, Gordon Research Conferences, Univ. of Rhode Island, Kingston, RI 02881–0801; tel.: 401-783-4011.)

Aug. 13–17 12th International Laser Radar Conference, Aix-en-Provence, France. Sponsors: IAMAP and AMS. (G. Megie or J. P. Gratier, Service D'Aeronomie du CNRS, 12th International Laser Radar Conference, BP 3, 91370-Verrieres le Buisson, France.) (Dec. 8, 1983.)

Aug. 14–17 Specialty Conference on Water for Resource Development, Coeur d'Alene, Idaho. Sponsor: Hydraulics Division of ASCE. (Harry Tuvel, American Society of Civil Engineers, 345 E. 47th St. New York, NY 10017–2398; tel.: 212-705-7494.)

Aug. 15–17 Conference on Practical Applications of Groundwater Models, Columbus, Ohio. Sponsors: National Water Well Association, International Groundwater Modeling Center. (David Nielsen, Conference Coordinator, National Water Well Association, 500 West Wilson Bridge Rd., Worthington, OH 43085; tel.: 614-846-9355.)

Aug. 19–22 Pathways and Future Directions for Environmental Data and Information Users, Denver, Colo. Sponsor: NOAA. (SES, Incorporated, P.O. Box 2097, Springfield, VA 22152.) (June 5, 1984.)

Aug. 20–24 Gordon Research Conference on Organic Geochemistry, Plymouth, N. H. Chairman: Keith Kvenvolden. (Alexander M. Cruickshank, Director, Gordon Research Conferences, Univ. of Rhode Island, Kingston, RI 02881–0801; tel.: 401-783-4011.)

Aug. 21–29 International Radiation Symposium '84 (IRS), Perugia, Italy. Sponsor: IAMAP Radiation Commission. (Giorgio Fiocco, Chairman, IRS '84, Dipartimento di Fisica, Città Universitaria, 00185 Rome, Italy; telex: INFNRO 613255.)

Aug. 22–26 Field Conference on Open System Behavior in Magmatic Evolution: Petrological, Geochemical, and Geophysical Constraints, Taos, N. Mex. Sponsor: Institute for the Study of Earth and Man. (Mike Dungan, Dept. of Geological Sciences, Southern Methodist Univ., Dallas, TX 75275; tel.: 214-692-2750.) (Jan. 17, 1984.)

Aug. 26–29 Geothermal Resources Council 1984 Annual Meeting, Reno, Nev. (Geothermal Resources Council, P.O. Box 1350, Davis, CA 95617; tel.: 916-758-2360.) (Feb. 7, 1984.)

Aug. 26–31 Seventh Australian Geological Convention, Sydney, Australia. Sponsor: Geological Society of Australia. (Secretary 7 AGC, P.O. Box 383, North Ryde, NSW, Australia 2113.) (Nov. 29, 1983.)

Aug. 27–31 Seventh IAHR Symposium on Ice, Hamburg, Germany. (J. Schwarz, Ice Engineering Div., Hamburgische Schiffbau-Versuchanstalt GmbH., P.O. Box 600 929, 2000 Hamburg, FRG.) (Nov. 22, 1983.)

Aug. 27–Sept. 6 General Assembly of URSI, Florence, Italy. (Vito Cappellini, IROE, Via Panciatichi 64, 50127 Firenze, Italy.) (Dec. 27, 1983.)

Aug. 29–31 Symposium on the Physics of Shallow Estuaries and Bays, Miami, Fla. Sponsors: ASCE Coastal Engineering Research Council, Rosenstiel School of Marine and Atmospheric Science. (Physics of Shallow Estuaries and Bays, c/o Division of Ocean Engineering and Applied Marine Science, RSMAS, Univ. of Miami, 4600 Rickenbacker Causeway, Miami, FL 33149; tel.: 305-361-4160.)

Sept. 3–7 Quadrennial Ozone Symposium, Halkidiki, Greece. Sponsors: IAMAP International Ozone Commission (IOC), Commission of the European Communities, the Academy of Athens, and WMO. (Christos S. Zerofos, Chairman, Local Organizing Committee, Physics Dept., Campus Box 149, Univ. of Thessaloniki, Thessaloniki, Greece. Send copy of information request to C. D. Walshaw, Secretary, IOC, Clarendon Laboratory, Oxford Univ., Parks Rd., Oxford, OX1 3PU, UK.)

Sept. 6–7 Conference on Stormwater and Water Quality Management Modeling, Hamilton, Ontario, Canada. (William James, Civil Engineering Department, McMaster University, Hamilton, Ontario, Canada, L8S 4L7.) (June 5, 1984.)

Sept. 9–14 Penrose Conference on the Geochemistry of the Environment Near a High-Level Nuclear Waste Repository, Mt. Hood, Oreg. Sponsors: Geological Society of America, Nuclear Regulatory Commission. (David Coles, Battelle Pacific Northwest Laboratories, P.O. Box 999, Richland, WA 99352.) (May 15, 1984.)

Sept. 9–14 American Society of Photogrammetry/American Congress on Surveying and Mapping Fall Technical Meeting, San Antonio, Tex. (Monica Mitain, 1984 ASP-ACSM Fall Convention, P. O. Box 8172, San Antonio, TX 78208.)

Sept. 10–12 Seventh Annual Madison Conference of Applied Research on Municipal and Industrial Waste, Madison, Wis. (Philip R. O'Leary, Dept. of Engineering and Applied Science, Univ. of Wisconsin-Extension, 432 North Lake St., Madison, WI 53706; tel.: 608-262-0493.)

Sept. 10–12 Oceans 84 Conference and Exhibition, Washington, D. C. Sponsors: Marine Technology Society, AGU, and Institute of Electrical and Electronics Engineers/Oceanic Engineering Society. (Oceans 84 Technical Program Committee, 1730 M St. N.W., Suite 412, Washington, DC 20036.) (Nov. 29, 1983.)

Sept. 10–14 International Symposium on Hydromechanical Balances of Fresh Water Systems, Stockholm/Uppsala, Sweden. Sponsors: Swedish Natural Science Research Council, UNESCO, and IAHS. (M. Falkenmark, Exec. Sec. NFRS, Comm. for Hydrology, Box 6711, S-11385 Stockholm, Sweden.)

Sept. 12–14 Seminar on Degradation, Retention, and Dispersion of Pollutants in Groundwater, Copenhagen, Denmark. Sponsor: International Association on Water Pollution Research and Control. (Erik Arvin, Dept. of Environmental Engineering, Building 115C, Technical Univ. of Denmark, DK-2800 Lyngby, Denmark.) (Dec. 13, 1983.)

Sept. 20–21 International Symposium on Environmental Pollution, Site To Be Announced. (V. M. Bhatnager, Box 1779, Cornwall, Ontario K6H 5V7, Canada.)

Sept. 24–25 Seminar: Enhanced Biological Removal of Phosphorus From Wastewater, Paris, France. Sponsor: International Association on Water Pollution Research and Control. (Michel Florentz, Phosphorus Seminar, Anjou-Recherche, 52, Rue d'Anjou, 75384 Paris Cedex 08, France; Tel.: 266–91–50; telex: Geneaux 280 332 F.) (Sept. 6, 1983.)

Sept. 24–26 International Water Well Exposition, Las Vegas, Nev. Sponsor: National Water Well Association. (National Water Well Association, 500 W. Wilson Bridge Rd., Worthington, OH 43085; tel.: 614-846-9355.)

Sept. 24–28 SLEADS (Salt Lakes, Evaporites, Aeolian Deposits) Workshop on Cenozoic Salt Lakes and Arid Zone Hydrology, Geochemis-

Meetings (cont. on p. 388)

Chapman Conference on Vertical Crustal Motion: Measurement and Modeling

A Chapman Conference on Vertical Crustal Motion: Measurement and Modeling will be held October 22–26, 1984, in Harpers Ferry, West Virginia.

Convenor: William E. Strange

This conference will bring together scientists who measure vertical crustal motions and those who analyze and model these motions with the primary objective of obtaining close interaction between the two groups. Emphasis will be on vertical crustal movement in North America. Questions to be addressed will be (1) what are the accuracies and error sources associated with each data type? (2) What is the extent of the current data base? (3) How accurately do we know vertical crustal motions in North America? (4) What are realistic expectations of contributions from space systems and other new technologies in the next decade? (5) What is the current status of modeling vertical crustal motions? (6) How important is vertical motion information to understanding and modeling earth dynamics? (7) What are the measurement requirements to support modeling and analysis in terms of temporal and spatial density and accuracy? (8) What are the most critical deficiencies of vertical motion data relative to modeling and analysis?

There will be invited and contributed presentations. The Call for Papers was published in the March 20, 1984, issue of Eos. Abstract deadline is August 1, 1984. Abstracts should be submitted to the American Geophysical Union.

For information on the required abstract format or further meeting logistics, contact:

AGU Meeting Department	For program information contact:
2000 Florida Avenue, N.W.	Dr. W. E. Strange
Washington, DC 20009	NOAA/NOS/CNGS/NGS/N/CG11
(202) 462-6903	6001 Executive Blvd.
	Rockville, MD 20852
	(301) 443-2520

Meetings (cont. from p. 387)

try, Stratigraphy, and Paleo-environments, Mallacoota, New South Wales, Australia. Sponsor: the Australian National Univ. (J. M. Bowler, Dept. of Biogeography and Geomorphology, Research School of Pacific Studies, Australian National Univ., GPO Box 4, Canberra 2601, Australia.) (March 27, 1984.)

Sept. 26–28 Seventh National Groundwater Quality Symposium, Las Vegas, Nev. Sponsor: National Water Well Association. (NWWA, 500 W. Wilson Bridge Rd., Worthington, OH 43085; tel.: 614-846-9355.)

Sept. 26–29 Symposium on the Quaternary of Virginia, Charlottesville, Va. Sponsor: Virginia Division of Mineral Resources. (S. O. Bird, Virginia Division of Mineral Resources, Box 3667, Charlottesville, VA 22903; tel.: 804-293-5121.)

Sept. 28–30 Tectonic Geomorphology—15th Annual Geomorphology Symposium, Binghamton, N.Y. Organizers: Marie Morisawa and John Hack. (Marie Morisawa, Dept. of Geological Sciences, SUNY, Binghamton, NY 13901; tel.: 607-798-2015.)

Oct. 1–5 International Symposium on Recent Investigations in the Zone of Aeration, Munich, FRG. Sponsor: Technical Univ. of Munich. (P. Udluft, RIZA Symposium, Institut für Wasserchemie der TU München, Marchioninistr. 17, D-8000 Munich 70, FRG.) (Dec. 20, 1983.)

Oct. 1–6 European Seismological Commission, Moscow. (Organizing Committee, ESC, Soviet Geophysical Committee, Molodezhnaya 3, 117 296 Moscow, USSR.)

Oct. 3–5 1984 Arctic Science Conference, Anchorage. (35th Alaska Science Conference), Anchorage. Sponsor: AAAS Arctic Division. (John Davies, P.O. Box 80271, Fairbanks, AK 99708; tel.: 907-474-7371.) (May 1, 1984.)

Oct. 3–5 Symposium on Meteorology and Oceanography of Northern High Latitudes, Anchorage, Alaska. Sponsors: American Meteorological Society and AAAS. (Stuart Bigler, National Weather Service, 701 C St., P.O. Box 23, Anchorage, AK 99513.) (March 6, 1984.)

Oct. 8–10 6th Annual Association of Earth Science Editors Conference, Portland, Oreg. (Association of Earth Science Editors, 4220 King St., Alexandria, VA 22302.)

Oct. 8–11 World Conference on Remote Sensing, Bayreuth, FRG. Sponsors: Univ. of Bayreuth, Texas Christian Univ. Center for Remote Sensing and Energy Research, and International Society of Toxicological and Environmental Chemists. (Leo W. Newland, Director, Environmental Sciences Program, Texas Christian Univ., Fort Worth, TX 76129; tel.: 817-921-7271.) (Feb. 7, 1984.)

Oct. 9–12 16th Annual Meeting of the Division for Planetary Sciences of the American Astronomical Society, Kailua-Kona, Hawaii. Sponsors: the Hawaii Institute of Geophysics and the Institute for Astronomy of the Univ. of Hawaii. (Tom McCord, Planetary Geosciences Division, Hawaii Institute of Geophysics, Univ. of Hawaii, 2525 Correa Road, Honolulu, HI 96822.) (April 24, 1984.)

Oct. 10–12 Seismological Society of America Eastern Section 56th Annual Meeting, St. Louis, Mo. (Robert B. Herrmann, Dept. of Earth and Atmospheric Sciences, St. Louis Univ., P.O. Box 8099, St. Louis, MO 63156; tel.: 314-658-3120.)

Oct. 10–13 New Mexico Geological Society 35th Annual Field Conference, Taos, N. Mex. (R. Rieker, General Chairman, Los Alamos National Laboratory, Mail Stop D446, Earth and Space Sciences Div., Los Alamos, NM 87545.) (Nov. 1, 1983.)

Oct. 13–16 Conference on the Origin of the Moon, Kona, Hawaii. Sponsors: Lunar and Planetary Institute, Division for Planetary Sciences of the American Astronomical Society. (Pam Jones, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, TX 77058.)

Oct. 15–17 First Multidisciplinary Conference on Sinkholes, Orlando, Fla. Sponsors: Florida Sinkhole Research Institute, University of Central Florida. (Barry Beck, Director, Florida Sinkhole Research Institute, University of Central Florida, Orlando, FL 32816; tel.: 305-275-2043.)

Oct. 15–21 IGCP Project 198: Evolution of the Northern Margin of Tethys, Bratislava, Czechoslovakia. Sponsor: International Geological Correlation Programme. (Alan Nairn, ESRI, Univ. of South Carolina, Columbia, SC 29208.)

Oct. 16–18 Statistics Symposium on National Energy Issues, Seattle, Wash. (Robert Kinnison, Statistics Section, Pacific Northwest Laboratory, P.O. Box 999, Richland, WA 99352.)

Oct. 16–19 International Symposium on Lake and Watershed Management: Local Involvement, McAfee, N.J. Sponsor: North American Lake Management Society. (Harry Gibbons, Jr., Dept. of Civil and Environmental Engineering, Washington State Univ., Sloan Hall 141, Pullman, WA 99164-2912.) (March 6, 1984.)

Oct. 17–19 AIPG Annual Meeting, Orlando, Fla. (Bobby J. Timmons, General Chairman, Timmons Associates, P.O. Box 50606, Jacksonville, FL 32250; tel.: 904-246-1353.)

Oct. 17–19 CRREL/ARO Workshop on the Interaction of Radar with the Seasonal Snow Cover, Cold Regions Research and Engineering Laboratory, Hanover, N. H. Sponsors: CRREL, AGU Hydrology Section. (S. C. Colbeck, CRREL, 72 Lyme Road, Hanover, NH 03755.)

Oct. 22–26 Chapman Conference on Vertical Crustal Motion Measurement and Modeling, Harpers Ferry, W. Va. Sponsor: AGU. (Vertical Motion Meeting, AGU, 2000 Florida Ave., N.W., Washington, DC 20009; telephone 202-462-6903 or toll-free 800-424-2488.)

Oct. 28–30 15th Underwater Mining Institute, Madison, Wis. (J. Robert Moore, Program Chairman, Univ. of Texas at Austin, Marine Science Institute, 200 East 26 1/2 St., Austin, TX 78705; tel.: 512-471-4816.)

Oct. 29–30 Conference on Methods for Evaluation of Groundwater Contamination Sites, East Lansing, Mich. Sponsors: Michigan Dept. of Natural Resources, Michigan State Univ., USGS. (David Hamilton, Michigan Dept. of Natural Resources, Stevens T. Mason Building, Box 30028, Lansing, MI 48909.)

Oct. 30–Nov. 3 Symposium on Relationships Between Climate of China and Global Climate—Past, Present, and Future, Peking, China. Sponsors: Academia Sinica, International Association of Meteorology and Atmospheric Physics (IAMAP), American Meteorological Society. (Jih-Ping Chao, Institute of Atmospheric Physics, Academia Sinica, Beijing, China.) (March 27, 1984.)

Oct. 31–Nov. 7 Regional Assembly of IASPEI, Hyderabad, India. (Mohan L. Gupta, Organizing Committee, IASPEI Regional Assembly, National Geophysical Research Institute, Hyderabad-500 007, India; telex: 155-478 NGRI IN; cable: Geophysics.) (Aug. 25, 1983.)

Nov. Mexican Geophysical Union Annual Meeting, La Paz, Baja California Sur, Mexico. (Union Geofisica Mexicana, A.C., Comite Organizador Reunion 1984, Apartado Postal 1805, Ensenada 22800, B.C.N. Mexico.)

Nov. 5–8 GSA Annual Meeting, Reno, Nev. (Jean Lauttippe, GSA, P.O. Box 9140, Boulder, CO 80301; tel.: 303-447-2020.)

Nov. 8–9 Illinois Lake and Watershed Management Conference, Springfield, Ill. Sponsors: University of Illinois Water Resources Center, AWRA Illinois section, North American Lake Management Society. (Glenn Stout, Water Resources Center, Univ. of Illinois, 2535 Hydrosystems Laboratory, 208 North Romine St., Urbana, IL 61801; tel.: 217-333-0536.)

Nov. 11–16 Engineering Foundation Conference on Ground-water Contamination, Santa Barbara, Calif. Sponsors: The Engineering Foundation, Universities Council on Water Resources. (Engineering Foundation, 345 E. 47th St., New York, NY 10017; tel.: 212-705-7835.)

Nov. 12–17 Water for South Africa, Johannesburg, South Africa. Sponsors: National Water Well Association and the Borehole Water Association of Southern Africa. (David M. Nielsen, Conference Coordinator, NWWA, 500 W. Wilson Bridge Rd., Worthington, OH 43085; tel.: 614-846-9355.) (Dec. 13, 1983.)

Nov. 13 Conference on Water Reuse and Desalination, Johannesburg, South Africa. Sponsor: National Water Well Association. (Pat Alcorn, NWWA, 500 W. Wilson Bridge Rd., Worthington, OH 43085; tel.: 614-846-9355.) (May 29, 1984.)

Nov. 13–15 Ophiolites Through Time, Nancy, France. (Jacqueline Desmons, Université de Nancy I, Faculté des Sciences, Laboratoire de Pétrologie, B.P. no. 239, F-54506 Vandoeuvre-lès-Nancy Cedex, France.)

Nov. 26–30 WMO Technical Conference on Urban Climatology and Its Applications With Special Regard to Tropical Areas, Mexico City. Sponsors: World Meteorological Organization, World Health Organization. (T. R. Oke, c/o World Climate Program Dept., World Meteorological Organization, 41, Giuseppe-Motta, Case postale No. 5, CH-1211 Geneva 20, Switzerland.)

Nov. 26–30 Symposium on the Scientific Basis for Nuclear Waste Management, Boston, Mass. Sponsor: Materials Research Society. (John Stone, E. I. du Pont de Nemours and Co., Savannah River Laboratory, Aiken, SC 29808.) (May 8, 1984.)

Nov. 27–30 Thirtieth Annual Conference on Magnetism and Magnetic Materials, San Diego, Calif. Sponsors: American Institute of Physics, Magnetics Society of IEEE. (John Scott, American Institute of Physics, 335 East 45th St., New York, NY 10017.) (June 5, 1984.)

Dec. 3–7 AGU Fall Meeting, San Francisco. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Dec. 16–21 International Chemical Congress of Pacific Basin Societies, Honolulu, Hawaii. Sponsors: ACS, Chemical Institute of Canada, and Chemical Society of Japan. (PAC CHEM '84, Meetings and Divisional Activities Dept., ACS, 1155 16th St., N.W., Washington, DC 20036; tel.: 202-872-4396; PAC CHEM '84, Chemical Institute of Canada, 151 Slater St., Suite 906, Ottawa, Ontario K1P 5H3 Canada; tel.: 613-233-5623; PAC CHEM '84, Chemical Society of Japan, 1-5, Kanda-Surugadai, Chiyoda-ku, Tokyo 101, Japan; tel.: 03-292-6161.) (Sept. 13, 1983.)

Dec. 28–31 Fourth International Conference on Applied Numerical Modeling, Tainan, Taiwan. (S. Y. Wang, School of Engineering, Univ. of Mississippi, University, MS 38677; tel.: 601-232-7219.)

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Jan. 7–12 17th International Congress on Hydrogeology of Rocks of Low Permeability, Tucson, Ariz. Sponsors: International Association of Hydrogeologists, AGU. (E. S. Simpson, Dept. of Hydrology and Water Resources, College of Engineering, Univ. of Arizona, Tucson, AZ 85721.)

Feb. 21–22 Sixteenth Annual Conference on Erosion Control Practices and Research, San Francisco. Sponsor: International Erosion Control Association. (Gerry Hester, Program Committee Chairman, International Erosion Control Association, Inc., P.O. Box 807, Freedom, CA 95019.) (May 29, 1984.)

March 10–15 Annual Spring Convention of Photogrammetry and American Congress on Surveying and Mapping National Meeting, Washington, D.C. (Willard A. Kuncl, 4415 Jensen Pl., Fairfax, VA 22032; tel.: 703-425-8790.)

March 11–15 Sixteenth Lunar and Planetary Science Conference, Houston, Tex. Sponsors: Lunar and Planetary Institute, AGU, NASA Johnson Space Center, Division for Planetary Science of the American Geological Society of America, Meteoritical Society. (Pamela Jones, Conference Administrator, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, TX 77058; tel.: 713-486-2150.)

April 1–4 European Union of Geosciences Biennial Meeting, Strasbourg, France. (Organizing Committee, Dept. of Earth Sciences, Univ. of Cambridge, Downing St., Cambridge CB2 3EQ, UK.)

April 8–11 Fifth Annual Front Range Branch Hydrology Days, Fort Collins, Colo. (H. J. Morel-Seytoux, Dept. of Civil Engineering, Colorado State Univ., Fort Collins, CO 80523; tel.: 303-491-5448 or 8549.)

April 14–19 GSA Penrose Conference on Geomorphic and Stratigraphic Indicators of Neogene-Quaternary Climatic Change in Arid and Semiarid Environments, Lake Havasu City, Ariz. Conveners: John Dohrenwend, USGS; Steve Wells and Les McFadden, Univ. of New Mexico. (John Dohrenwend, U.S. Geological Survey, MS 911, 345 Middlefield Rd., Menlo Park, CA 94025.)

April 15–19 First International Symposium on Precise Positioning with the Global Positioning System, Rockville, Md. Sponsors: IAG, IUGG, Defense Mapping Agency, NOAA. (Positioning with GPS-1985, White Flint Mall, Post Office Box 2095, Kensington, MD 20895.)

April 21–26 Third International Symposium on the North American Vertical Datum, Rockville, Md. Sponsors: IAG, NOAA, National Geodetic Survey. (Gary M. Young, Asst. Director, NAVD Symposium 85, White Flint Mall, P. O. Box 2095, Kensington, MD 20895; tel.: 301-443-8567.)

April 28–May 1 International Conference on Acidic Water Pollution Research Applications of Science and Technology, Yellowknife, Northwest Territories, Canada. Organizer: Canadian National Committee, International Association on Water Pollution Research and Control. (K. Charbonneau, National Research Council of Canada, Montreal Road Laboratories, Ottawa K1A OR6, Canada; tel.: 613-993-0009.)

April 30–May 1 Symposium on Watershed Management, Denver, Colo. Sponsor: American Society of Civil Engineers. (E. Bruce Jones, President, Resource Consultants, Inc., P.O. Box Q, Fort Collins, CO 80522.) (May 1, 1984.)

May 27–31 AGU Spring Meeting, Baltimore, Md. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

Summer Colloquium on Comparative Study of Magnetospheric Systems, France. (Dominique Le Quéau and Bent Moeller-Pedersen, DASOP, Observatoire de Meudon, F 92195, Meudon Principal Cedex, France; Telex: 200 590 CNET OBS.) (Aug. 9, 1983.)

June 4–7 International Conference on Mafic Dyke Swarms, Mississauga, Ontario. Sponsors: IUGS Commission on Tectonics, the International Lithosphere Programme and the Geological Survey of Canada. (H. C. Halls, Erindale Campus, University of Toronto, Mississauga, Ontario, Canada L5L 1C6; tel.: 416-828-5363.)

June 9–15 IWRA Fifth World Congress, Brussels, Belgium. (Fifth World Congress On Water Resources, Brussels International Conference Center, Parc des Expositions, Tentoonstellingspark, B-1020 Brussels, Belgium; tel.: 32-2-478-48-60; telex: 23-645.) (Aug. 30, 1983.)

June 16–21 Third International Symposium on Analysis of Seismicity and Seismic Risk, Liblice, Czechoslovakia. (Z. Schenkova, Geophysical Institute, Bocni II, 14131 Prague 4, Czechoslovakia.)

June 26–28 U.S. Symposium on Rock Mechanics, Rapid City, S. Dak. Sponsor, South Dakota School of Mines and Technology. (Eileen Ashworth, Chairman, 26th U.S. Symposium on Rock Mechanics, Dept. of Mining Engineering, South Dakota School of Mines and Technology, Rapid City, SD 57701-3995; tel.: 605-394-2344.)

July 8–10 International Hydrology Symposium, Fort Collins, Colorado. Sponsors: AGU Hydrology Section, International Association of Hydrological Sciences, ASCE, IWRA, IAHR. (H. W. Shen, Dept. of Civil Engineering, Hydrology and Water Resources Program, Foothills Campus, Colorado State University, Fort Collins, CO 80523.)

July 29–Aug. 9 Tsunami 85: International Tsunami Symposium of the IUGG Tsunami Commission, Victoria, Canada. (Tsunami 85, P.O. Box 2267, Sidney, B.C., Canada V8L 3S8; tel.: 604-656-8343.)

August International Workshop on Hydrologic Applications of Space Technology Input to Hydrologic Models and Geographic Information Systems, Florida. Sponsors: IAHS, WMO. (A. Ivan Johnson, President, IAHS International Committee on Remote Sensing and Data Transmission, 7474 Upham Court, Arvada, CO 80003.)

Aug. 5–16, 1985 IAMAP/IAPSO Joint Scientific Assembly on the Large Scale Circulations of the Oceans and Atmosphere and their Interactions, Honolulu, Hawaii. Sponsors: IAMAP, IAPSO, AGU. (AGU, 2000 Florida Ave. NW, Washington, DC 20009.)

Aug. 5–17 Symposium on Magnetic Anomalies over the Margins of Continents and Plates, Prague, Czechoslovakia. Sponsor, International Association of Geomagnetism and Aeronomy. (William J. Hinze, Dept. of Geosciences, Purdue Univ., West Lafayette, IN 47907; tel.: 317-494-5982.) (Feb. 7, 1984.)

Aug. 11–15 21st Annual AWRA Conference on Water Demand: Sharing a Limited Resource and Symposium on Groundwater Contamination and Reclamation, Tucson, Ariz. Sponsor: AWRA. (Nathan Buras, Dept. of Hydrology and Water Resources, University of Arizona, Tucson, AZ 85721.)

Aug. 19–23 Sixth Gondwana Symposium, Columbus, Ohio. Sponsor, GSA. (D. Elliot, Ohio State Univ., Institute of Polar Studies, 103 Mendenhall, 125 South Oval Mall, Columbus, OH 43210.)

Aug. 19–24 Fourth Chilean Geological Congress, Antofagasta, Chile. Sponsor: Dept. of Geociences, Universidad del Norte. (Organizing Committee, Fourth Chilean Geological Congress, Departamento de Geociencias, Universidad del Norte, Casilla (Box) 1280, Antofagasta, Chile; tel.: 222040–205.)

Aug. 19–30 23rd General Assembly of IASPEI, Tokyo, Japan. (Ryosuke Sato, Secretary-General of the 23rd General Assembly of IASPEI, c/o Inter Group Corp., Akasaka Yamakatsu Bldg., 8-5-32, Akasaka, Minato-ku, Tokyo 107, Japan; tel.: Tokyo (03) 479-5511.)

Aug. 26–30 International Symposium on Geothermal Energy, Kailua-Kona, Hawaii. Sponsor: Geothermal Resources Council. (Geothermal Resources Council, P. O. Box 1350, Davis, CA 95617; tel.: 916-758-2360.)

September International Symposium on Variational Methods in Geosciences, Norman, Okla. Sponsors: Cooperative Institute for Mesoscale Meteorological Studies, Univ. of Oklahoma College of Geosciences. (Y. K. Sasaki, Univ. of Oklahoma, 815 Jenkins, Norman, OK 73019.)

Sept. 16–21 Symposia on Potassic Volcanism and Etna Volcano, Catania, Italy. Sponsor: IAVCEI. (G. Frazzetta and G. Lanzafame, Istituto Internazionale di Vulcanologia, V.le R. Margherita, 6, Catania, Italy.) (Dec. 27, 1983.)

Sept. 17–21 AIPG Annual Meeting, St. Paul, Minn. (Robert E. Prendergast, General Chairman, Geotechnical Engineering Corp., 1925 Oakcrest Ave., Roseville, MN 55113; tel.: 612-636-7744.)

Oct. 9–10 International Symposium on Management of Hazardous Chemical Waste Sites, Winston-Salem, N. C. Sponsors: International Association of Engineering Geology U. S. National Committee, Association of Engineering Geologists. (Norman Tilford, Dept. of Geology, Texas A & M Univ., College Station, TX 77843–3115; tel.: 409-845-9682.)

Oct. 21–25 International Conference on Arid Lands: Today and Tomorrow, Tucson, Ariz. Sponsors: UNESCO, Univ. of Arizona. (G. P. Nabhan, Office of Arid Land Studies, Univ. of Arizona, Tucson, AZ 85721.)

Oct. 28–31 Geological Society of America 1985 Annual Meeting, Orlando, Fla. (Sue Beggs, Meetings Manager, GSA, P.O. Box 9140, Boulder, CO 80301; tel.: 303-447-2020.)

Dec. 2–13 AGU Fall Meeting, San Francisco. (Meetings, AGU, 2000 Florida Ave., N.W., Washington, DC 20009.)

1986

January Symposium on Geotechnical Applications of Remote Sensing and Remote Data Transmission, New Orleans, La. Sponsor: American Society for Testing and Materials. (A. Ivan Johnson, Woodward-Clyde Consultants, Harlequin Plaza-North, 7600 E. Orchard Road, Englewood, CO 80111; tel.: 303-425-5610.)

April 21–24 International Symposium on Environmental Geotechnology, Allentown, Pa. (H. Y. Fang, Symposium Chairman, Geotechnical Engineering Division, Dept. of Civil Engineering, Lehigh Univ. No. 13, Bethlehem, PA 18015.)

May 18–21 International Symposium on Flood Frequency and Risk Analyses, Baton Rouge, La. (Vijay Singh, Louisiana State Univ., Dept. of Civil Engineering, Baton Rouge, LA 70803–6405; tel.: 504-388-6697.)

June, 1986 Conference on Study and Mitigation of Hazards, San Martin. Sponsor: Tsunami Society. (Hazards Conference, Box 60536, Las Vegas, NV 89160.) (January 3, 1984.)

Sept. 7–12 Second International Conference on Paleoceanography, Woods Hole, Mass. (W. A. Berggren, Dept. of Geology and Geophysics, Woods Hole Oceanographic Institution, Woods Hole, MA 02543.)

AAAS American Association for the Advancement of Science
AAPG American Association of Petroleum Geologists
ACS American Chemical Society
AIPG American Institute of Professional Geologists
AMS American Meteorological Society
ASCE American Society of Civil Engineers
AWRA American Water Resources Association
GSA Geological Society of America
IAG International Association of Geodesy
IAGA International Association of Geomagnetism and Aeronomy
IAHR International Association for Hydraulic Research
IAHS International Association of Hydrological Sciences
IAMAP International Association of Meteorology and Atmospheric Physics
IAPSO International Association for the Physical Sciences of the Ocean
IASPEI International Association of Seismology and Physics of the Earth's Interior
IAVCEI International Association of Volcanology and Chemistry of the Earth's Interior
ICSU International Council of Scientific Unions
IUGG International Union of Geodesy and Geophysics
IUGS International Union of Geological Sciences
IWRA International Water Resources Association
MSA Mineralogical Society of America
SEG Society of Exploration Geophysicists
SEPM Society of Economic Paleontologists and Mineralogists
URSI International Union of Radio Science
WMO World Meteorological Organization

AGU

Membership Applications Received

Applications for membership have been received from the following individuals. The letter after the name denotes the proposed primary section affiliation.

Regular Members

Charles Andrews (H), Joanne Bourgeois (O), Eric L. Butler (O), Georgina Cantoni (T), George H. Carlson (H), Philip Carrion (S), Robert A. Castle (G), Simon W. Chang (A), Mohammed El-Sabh (O), Steven Emerson (O).

Judy Flerstein (V), Leslie Gesell (A), David L. Glackin (A), Denise Graves (A), Martin I. Hoffert (A), John Kanellopoulos (A), Jayne F. Knott (H), Nels R. Larson (A), Dong Soo Lee (O), Julian Marsh (V), Eric Medlin (T), Anne Meltzer (T).

Nitzan Rabinowitz (S), Young-Jae Ro (O), José M. Rodriguez (SA), Asbury H. Sallenger (O), Erwin Scheibner (T), C. P. Scofield (S), James V. Scrivner (V), Arni Snorrason (H), Robert Sterrett (H).

Walter S. Urbanski (V), Rutger Wahlstrom (S), Philip A. Walen (S), John R. Wiesenfeld (A), Dan Winske (SM), A. Michelle Wood (O), P. Jane Wynne (GP), Richard Yuretich (H).

Student Status

John Baker (A), Wayne A. Basden (S), Tom A. Brikowski (V), Darcy Campbell (H), Tianqing Cao (S), David Chason (H), Yongshun Chen (T), Steve Chipera (V), Matthew J. Cordery.

Philip L. De Groot (H), Ron Elan (V), Lydia K. Fox (V), Mark Fries (H), David W. Glover (S), Scott Hammond (A), Vicki Hansen (T), Siamak Hassanzadeh (S), Larry D. Hinman (H), Ching-Hui Hsu (O).

Erik Jackson (S), Robert B. Jacobson (H), Joshua L. Jenkins (H), Bradley L. Jolliff (V), Felicia J. Kegel (T), Kelly L. Kenison (O), Eirik J. Krogstad.

Jung Mo Lee (T), David A. Lisle (S), Paula Luborsky (H), Calum MacDonald (S), Ian Madin (T), Stephen R. Mateskon (T), Cecelia McCloy (O), Richard McKinney (O), Debra Meese (A), James F. Milne (S), Martin Lane Mitchell (O).

Carlos E. Nunez (S), Jeffrey L. Peterson (H), Bernard Pisarchick (T), William M. Powers (S), Carol J. Ptacek (H), Howard W. Reeves (H), Jeffrey Ridgway (GP), Stephen Ridley (T), Scott D. Sachs (T), Frederick Sontena (H), Thomas Stanton (V), Robert Striegl (H), Arnon Sugar (T), Stephen T. Sutton (T).

Margaret A. Thomas (V), Lisa Toothaker (H), Vanessa Wesley (S), S. T. Whitlow (O), Mark Thomas Winter (T), G. B. Wolbert (H), Robert Yonover (V).

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Separates

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Aeronomy

0460 Tides waves and winds
THERMOSPHERIC CIRCULATION TEMPERATURE AND COMPOSITIONAL STRUCTURE OF THE SOUTHERN HEMISPHERE DURING OCTOBER-NOVEMBER 1981
R. G. Roble (National Center for Atmospheric Research*, Boulder, Colorado 80307), B. A. Emery, R. E. Dickinson, E. C. Ridley, T. L. Killeen, P. B. Hays, G. R. Carignan and N. W. Spencer

Thermospheric temperature, composition and winds at F-region heights over the Southern Hemisphere polar cap have been measured by the Dynamics Explorer (DE-2) satellite during October-November 1981. Perigee of the DE-2 satellite during this period was over the Southern Hemisphere polar cap, and measurements made along 0900-2100 local time polar passes are used to determine the average Universal Time dependence of thermospheric properties for this local time slice. The F-region wind vector is derived from the meridional wind component measured by the Fabry-Perot interferometer (FPI) and the zonal wind component measured by the wind and temperature spectrometer (WATS) instruments on board DE-2. The neutral gas temperature is derived from FPI and WATS measurements, and the compositional structure is determined from the neutral atmosphere composition spectrometer (NACS) instrument. The measured temperature, composition and winds along the 0900-2100 local time polar passes all display a Universal Time dependence that is due to the displacement between geomagnetic and geographic poles. The temperature and molecular nitrogen densities are enhanced and the atomic oxygen density is reduced in the magnetic polar cap compared to lower-latitude regions. The neutral wind pattern follows the pattern of ion drift associated with magnetospheric convection.

The NCAR thermospheric general circulation model (TGCM) is used to calculate the temperature, composition and winds over the Southern Hemisphere polar cap region for conditions similar to October 1981. The TGCM includes separated geographic and geomagnetic poles. The temperature, composition and winds are determined along the DE-2 satellite track for various Universal Times. The calculated winds are in general agreement with the observed winds, with both having a two-cell pattern of magnetospheric convection. The calculated and observed composition patterns are also in general agreement with predictions made by the MSIS-83 empirical model when models and observations are normalized to the same constant pressure surface. The calculated and observed maximum compositional variations in the magnetic polar cap occur near 0300 UT, when the dawn sector of the auroral oval passes over the south geographic pole. The overall pattern of the calculated temperature variation is similar to that observed except for the period between 1300 and 1500 UT. Better agreement with temperature in this time range is obtained with the inclusion of auroral particle precipitation within the magnetospheric cusp.

J. Geophys. Res., A, Paper 4A0759

Electromagnetics

0720 Electromagnetics
WAVE INSTABILITIES IN ELECTRON BEAMS TRAVELLING THROUGH MEDIA WITH A RANDOM DIELECTRIC CONSTANT OVER A ROUGH SURFACE
F.G.Bass, A.A.Bulgakov, G.M.Pritula, S.I.Khankina, and Y.M.Yakovenko (Institute of Radiophysics and Electronics, Academy of Sciences of the Ukrainian SSR, Kharkov, 310085, USSR)

A new type of the beam instability is analysed which results from energy exchange between the fast and slow waves in a beam of charged particles. The interaction is conditioned by a random non-uniformity of either the medium or the surface. The power necessary for wave amplification is provided by a d.c. electric field source. (Instability, electron beam, random media).

Rad. Sci., Paper 4S0746

Exploration Geophysics

0910 Magnetic and electrical methods.
THE ROLE OF SIMPLE COMPUTER MODELS IN INTERPRETATIONS OF WIDE-BAND, DRILL-HOLE ELECTROMAGNETIC SURVEYS IN MINERAL EXPLORATION
Alfred V. Dyck (Geological Survey of Canada, 601 Booth Street, Ottawa, Ont., Canada K1A 0E8) Gordon F. West

Drill-hole geophysical surveys are a means of extending the search for massive-sulfide deposits to depths which are inaccessible to conventional surface techniques. The present investigation combines field and model studies of an electromagnetic (EM) prospecting method which utilizes a large, fixed transmitter loop with a downhole, axial-component magnetic field sensor (solenoid). The system is shown to be well-suited for detection of deeply buried massive-sulfide conductors located in resistive host rock at appreciable distances from the drill hole. We propose that drill-hole survey data collected with a wide-band large-loop EM system can be routinely used for estimating target parameters by forward modeling with two simple conductor shapes: a plate and a sphere in free space. Analysis of confined conductors is facilitated by "eigencurrent decomposition" of the induced current vortex into a set of noninteracting loops with simple RL-circuit behavior. Solutions have been implemented in interactive computer programs which are fast, inexpensive, and sufficiently versatile to accommodate configurations and waveforms used in many practical EM systems.

Both stationary and dynamic aspects of the induction process are exploited for diagnosis of three-dimensional targets. Field studies at test sites in Sudbury and Noranda base-metal mining areas with a commercial pulse EM system indicate that many important effects predicted by the model studies are, indeed, observable in survey data.

GEOPHYSICS, VOL. 49, NO. 7

0930 Seismic methods
A METHOD OF DETERMINING A PREFERRED P-WAVE VELOCITY PROFILE IN A BOREHOLE USING SURFACE EXPLOSIONS
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The interpretation of seismic velocity variations in crystalline rocks in terms of fracture parameters requires velocity measurement with errors no greater than 1-2 percent. To achieve optimum resolution, we have devised a method of calculating P velocity-depth profiles from crystal-cable well surveys that makes maximum use of the data redundancy. Relative time corrections are overlapping portions of the hydrophone array between consecutive shots. From the resulting traveltime versus distance curve, a family of possible velocity solutions is obtained for data windows of various lengths using Bolt's modification of the method of summary values devised by Jeffreys. Trade-off curves between the number of data points in the window and the variance of the velocity estimates are then drawn for different regions of the velocity profile. This enables a preferred solution to be constructed for each section of the velocity profile. The preferred velocity-depth curve for a region of a gneiss-monzonite rock body at depths between 25 and 254 m shows minima that correlate with the positions of major fractures or high concentrations of fractures inferred from optical examination of core samples, laboratory measurement of velocities, and tube wave studies.

GEOPHYSICS, VOL. 49, NO. 7

Geochemistry

1499 General (Plutonium Migration)
RESIDUAL PLUTONIUM MIGRATION IN SOIL OF NAGASAKI
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Most of the plutonium contamination of the surface soil in Nagasaki originated from the explosion of the plutonium atomic bomb in 1945. The highest level of plutonium contamination was discovered in the soil at the northeast edge of the Nishiyama reservoir and the level was 10 - 30 times higher than in other areas of Nagasaki in which was still at the typical accumulated level of the global fallout. The residual plutonium concentration in the Nishiyama soil was vertically observed from the ground surface to a depth of 2.25m, in order to measure the plutonium underground migration rate under the natural environmental conditions in a long term. During the past 36 years, a large part (~97%) of plutonium moved down to a depth of 0.1 - 0.3m from the ground surface. The mean plutonium migration rate in a clay silt loam in the Nishiyama district was estimated at 1.25 myr^{-1}, compared to the mean infiltration rate of rainwater of 2.5 myr^{-1}. (Residual plutonium, fallout, underground migration, Nagasaki).

J. Geophys. Res., B, Paper 4B0604

Geodesy and Gravity

1930 High-order harmonics of the gravity potential field and local gravity anomalies
GRAVITY EMPIRICAL COVARIANCE VALUES FOR THE CONTINENTAL UNITED STATES
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Variances and correlation distances have been determined for terrain corrected Bouguer anomalies in all 30' x 30' blocks covering the continental United States. Also linear trend values were subtracted from the data.

In order to make the determination independent of the frequently irregular local data distribution, gravity values predicted in a regular grid were used. The prediction was made using least-squares collocation, constructing local surfaces representing the gravity anomalies for each 30' x 30' block. For this purpose 544000 terrain corrected Bouguer anomalies were available in the U.S. National Geodetic Survey gravity data base. Therefore, in order to limit the computational effort, a sequence of surfaces were determined by selecting in each block an increasing number of data points until a limit of the absolute value of the error equal to 4 mgal was reached. This procedure reduced the number of gravity observations used per block to a very few (in areas of little gravity variation) to maximally 188.

The correlation distance was found to be smallest in areas of high topography. Large variances are associated with the mid-continental gravity high and tectonic features on the Pacific coast.

J. Geophys. Res., B, Paper 4B0740

Geomagnetism and Paleomagnetism

2560 Time variations, Paleomagnetism
PALEOMAGNETIC AND GEOLOGIC DATA INDICATING 2500 KM OF NORTHWARD DISPLACEMENT FOR THE SALINIAN AND RELATED TERRANES, CALIFORNIA
D.E. Champion (U.S. Geological Survey, 345 Middlefield Road, Menlo Park, Ca,94025), D.G. Howell and C.S. Gromme

Results of a pair of paleomagnetic studies of sedimentary rocks in the Salinian terrane of westernmost California indicate a northward displacement of about 2,500 km since Cretaceous time. Stratigraphic relations suggest that the Salinian terrane became amalgamated with several others by the late Cretaceous and all underwent the same northward translation. This composite terrane (allochthon) became sutured to cratonal North America by early Tertiary time. One paleomagnetic study involved Upper Cretaceous turbidites of the Pigeon Point Fm. Fine-grained, thin-bedded turbidites yielded the most reliable results, whereas medium to coarse-grained sandstone are not always stably magnetized. Contorted layers resulting from soft sediment deformation usually gave directional results parallel to those of undeformed sedimentary layers, thereby implying a post-depositional remanence process. There is no indication of inclination error or other processes affecting the fidelity of the remanent magnetization. Paleomagnetic results from 4 separate locations in the Pigeon Point Formation gave positive fold tests and mean inclination values near 36 degrees. A mean geomagnetic latitude calculated from these results is 21.2 ± 5.3 degrees, much more southerly than the value of 46.5 ± 2.3 degrees calculated for Pigeon Point using paleomagnetic pole data from late Cretaceous rocks from cratonic North America. Declination values are not antipodal for normal and reversed polarity sites. Analysis of depositional current directions from sandstone beds of the same outcrops shows that the difference is the result of Neogene rotations of small crustal blocks adjacent to the San Gregorio Fault. In a sequence of Paleocene turbidites that crop out at Point San Pedro, 4 sample localities yielded positive fold tests with mean inclination values near 40 degrees. Declination values, however, were spread over a range between 230 and 320 degrees. Comparison with depositional current directions from the same outcrops indicates clockwise rotations related to Neogene right slip on the Pilarcitos Fault. The mean geomagnetic latitude calculated for the Point San Pedro sediments is 24.5 ± 4.0 degrees, and is more southerly than the 43.3 ± 2.5 degree latitude expected for that location. For the Salinian terrane and the west coast of cratonic North America, absolute rates of latitudinal motion were 8.5 cm/yr northward and 3 cm/yr southward respectively. (paleomagnetism, accretionary tectonics)

J. Geophys. Res., B, Paper 4B0520

2599 General
PALEOMAGNETIC STUDY OF THRUST SHEET ROTATION DURING FORELAND IMPINGEMENT IN THE WYOMING-IDAHO OVERTHRUST BELT
S.Y. Schwartz and R. Van der Voo (Department of Geological Sciences, University of Michigan, Ann Arbor, MI 48109)

Upper Jurassic and Lower Cretaceous strata in the Darby and Absaroka thrust sheets were sampled in order to paleomagnetically evaluate thrust sheet rotation in the Wyoming-Idaho overthrust belt. No significant rotations were found. Lack of rotation in these thrust sheets suggests that previously reported rotation of the Prospect thrust sheet was not transmitted to the older Darby and Absaroka thrust sheets, indicating that the Prospect thrust sheet only experienced local rotations in response to collision with the Teton-Gros Ventre uplift. The Upper Jurassic Stump Formation possesses a magnetization that passes the fold test and gives a paleomagnetic pole of 64°N, 170°E (K=18, A95=9°), in good agreement with other published Upper Jurassic poles for cratonic North America. Samples from all Lower Cretaceous sites are believed to possess a synfolding remagnetization of chemical origin.

J. Geophys. Res., B, Paper 4B0595

Hydrology

3110 Hydrology (Erosion and Sedimentation)
A PROBABILISTIC APPROACH TO THE SPATIAL ASSESSMENT OF RIVER-CHANNEL INSTABILITY
Wm L. Graf (Department of Geography, Arizona State University, Tempe, Arizona, 85287)

The deterministic approach to the analysis of river-channel instability has not proved to be a completely useful basis for geographic predictions of channel behavior. Economic estimates for benefits of structural channel control projects commonly account for flood inundation, but in arid and semi-arid regions these estimates are incomplete because they fail to take into account destructive channel migration and erosion. As a solution, a method whereby historical records of channel locations are reduced to spatially defined probabilistic functions allows calculation of the probability that given parcels of near-channel terrain will be destroyed by erosion. The probability of erosion for any given parcel over a given period of time is directly proportional to the sizes of the annual floods during the period and inversely proportional to two distance measures: distance upstream and distance laterally to the channel. In a test of the probabilistic geographic method using data on the locations of Rillito Creek, Arizona, from 1871-1978, erosion probability maps accurately characterized the locations of observed changes. In a 50-year simulated period erosion ultimately produced economic losses that were five times greater than potential inundation losses. (Fluvial processes, channel migration, erosion, spatial analysis).

Water Resour. Res., Paper 4W0320

3130 Groundwater
PARAMETER IDENTIFICATION OF GROUNDWATER AQUIFER MODELS: A GENERALIZED LEAST SQUARES APPROACH
J. Sadeghipour (Civil Engineering Department, University of California, Los Angeles, California, 90024), W. W-G. Yeh

This paper concerns the methods of estimating aquifer transmissivities on the basis of unsteady state hydraulic head data. Traditionally, the criterion of minimizing the sum of the squares of errors has been used to match the observed data with the model response. The data used for optimization usually contain noise which is not necessarily uncorrelated. It is well understood that the results of identification methods are very sensitive to measurement errors in data. In this study, the Ordinary Least Squares (OLS) technique is carried out along with a Generalized Least Squares (GLS) technique which is specifically designed to reduce the effect of correlated errors. The trace of the covariance matrix is used as a measure of overall accuracy and reliability of the estimated parameters. The effectiveness of the OLS and GLS techniques in dealing with noisy data is demonstrated by using a hypothetical example. The results of numerical experiments suggest that GLS offers a promising approach in efficiently improving the reliability of the estimated parameters.

Water Resour. Res., Paper 4W0284

3130 Groundwater
DOUBLE-POROSITY MODELS FOR A FISSURED GROUNDWATER RESERVOIR WITH FRACTURE SKIN
A.F. Moench (U.S. Geological Survey, Menlo Park, CA, 94025)

Theories of flow to a well in a double-porosity, groundwater reservoir are modified to incorporate effects of a thin layer of low-permeability material or fracture skin that may be present at fracture-block interfaces as a result of mineral deposition or alteration. The commonly used theory for flow in double-porosity formations that is based upon the assumption of pseudo-steady state, block-to-fissure flow is shown to be a special case of the theory presented in this paper. The latter is based on the assumption of transient, block-to-fissure flow with fracture skin. Under conditions where fracture skin has a hydraulic conductivity that is less than that of matrix rock it may be assumed to impede the interchange of fluid between the fissures and blocks. Resistance to flow at fracture-block interfaces tends to reduce spatial variation of hydraulic-head gradients within the blocks. This provides theoretical justification for neglecting the divergence of flow in the blocks as required by the pseudo-steady state flow model. Coupled boundary value problems for flow to a well discharging at a constant rate were solved in the Laplace domain. Both slab-shaped and sphere-shaped blocks were considered, as were effects of well-bore storage and well-bore skin. Results, obtained by numerical inversion, were used to construct dimensionless type curves that were applied to well-test data, for a pumped well and observation well, from the fractured, volcanic-rock terrane of the Nevada Test Site. (Well hydraulics, fractured rock, Laplace transform).

Water Resour. Res., 4W0381

3160 Runoff and Streamflow
ON THE TREATMENT OF EVAPOTRANSPIRATION, SOIL-MOISTURE ACCOUNTING AND AQUIFER RECHARGE IN MONTHLY WATER BALANCE MODELS
William M. Alley, (U.S. Geological Survey, Reston, Virginia, 22092)

Several two-to-six parameter regional water balance models are examined using 50-year records of monthly streamflow at 10 sites in New Jersey. These models include variants of the Thornthwaite-Mather model, the Palmer model, and the more recent Thomas abcd model. Calibration and prediction errors are relatively similar among the models. However, simulated values of state variables such as soil-moisture storage differ substantially among the models, and fitted parameter values for different models sometimes indicated an entirely different type of basin response to precipitation. Some problems in parameter identification are noted including difficulties in identifying an appropriate time-lag factor for the Thornthwaite-Mather-type model for basins with little groundwater storage, very high correlations between upper and lower storages in the Palmer-type model, and large sensitivity of parameter a of the abcd model to bias in estimates of precipitation and potential evapotranspiration. Modifications to the threshold concept of the Thornthwaite-Mather model were statistically valid for the 6 stations in northern New Jersey. The abcd model resulted in a simulated seasonal cycle of groundwater levels similar to fluctuations observed in nearby wells but with greater persistence. These results suggest that extreme caution should be used in attaching physical significance to model parameters and in using the state variables of the models in indices of drought and basin productivity. (Water balance models).

Water Resour. Res., Paper 4W0480

3160 Runoff and Streamflow
ALTERATION OF STREAMFLOW CHARACTERISTICS FOLLOWING ROAD CONSTRUCTION IN NORTH-CENTRAL IDAHO
[illegible] King (USDA Intermountain Forest and Range Experiment Station, 1221 S. Main, Moscow, ID 83843) and L. C. Tennyson

Effects of logging access roads on seven streamflow

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spheric transmission function of the form: $\varepsilon^* = (B_y^2 + B_z^2)^{1/2} \cos\theta/2$, where θ is the angle between the positive z-axis and IMF. If the magnetic disturbances are interpreted in terms of Birkeland currents, they flow downward on the dusk side and flow away on the morning-side (identical to the cusp current flow reported by Iijima and Potemra, 1976b). We interpret these observations as evidence for a large-scale, stable Birkeland current system in the polar region which is associated with merging on field lines in the geomagnetic tail. This current system intensifies and is more stable as B_z becomes more northward (reminiscent of the behavior of the Region 1 current system with increasing southward values of B_z). The new stable polar cap current system described here is referred to as the "NBZ" Birkeland current system for "northward B_z" and is important because of its relationship to a variety of other "northward B_z" phenomena such as polar cap auroral arcs ("theta aurora") and multi-cell convective flow patterns. The existence of these stable NBZ currents and the correlation of their amplitudes with the IMF substantiates the fact that energy continues to flow to the Earth's polar regions during periods of strongly northward IMF.

J. Geophys. Res., A, Paper 4A0752

5720 Interactions between solar wind and magnetosphere
DIRECT EVIDENCE FOR SOLAR WIND CONTROL OF JUPITER'S HECTOMETER WAVELENGTH RADIO EMISSION
M. D. DESCH (NASA/Goddard Space Flight Center, Greenbelt, MD, 20771), C. H. Barrow
Observations of the solar wind close to Jupiter, by the Voyager 1 and Voyager 2 spacecraft in 1978 and 1979, are compared with the hectometer-wavelength radio emission from the planet. A significant positive correlation is found between variations in the solar wind plasma density at Jupiter and the level of Jovian radio emission output. During the 173-day interval studied for the Voyager 2 data, the radio emission displayed a long-term periodicity of about 13 days, identical to that shown by the solar wind density at Jupiter and consistent with the magnetic sector structure association already proposed for groundbased observations of the decameter-wavelength emission. (Jupiter, radio emission, Voyager, solar wind).
J. Geophys. Res., A, Paper 4A8026

5720 Interaction between solar wind and magnetosphere
INTERPLANETARY MAGNETIC FIELD CONTROL OF HIGH-LATITUDE ELECTRIC FIELDS AND CURRENTS DETERMINED FROM GREENLAND MAGNETOMETER DATA
E. Friis-Christensen (Division of Geophysics, Danish Meteorological Institute, Lyngbyvej 100, DK-2100 Copenhagen, Denmark,
Y. Kamide, A.D. Richmond, S. Matsushita
To determine the effects of the interplanetary magnetic field (IMF) on the electric potential as well as on ionospheric and field-aligned currents, a recently available numerical algorithm is applied to an empirical model of high-latitude magnetic perturbations, parameterized in terms of the B_y- and B_z-components of the IMF. The calculated results reproduce fairly well overall features of the influence of the IMF on high-latitude electric fields which have been reported on the basis of more direct measurements. In addition, our results indicate that the system of ionospheric and Birkeland currents near the polar cusp, which has been shown to depend strongly on B_y, exists independently of the system of region 1 and region 2 field-aligned currents, which, on the other hand, depends strongly on B_z. The direction of the field-aligned currents in the dayside polar cap is uniquely controlled by the sign of the B_y component of the IMF, namely upward currents for $B_y>0$ in the northern polar cap and oppositely directed for $B_y<0$. At the dayside boundary of the polar cap the DPY ionospheric Hall current is sandwiched between the polar cap field-aligned currents and an oppositely directed current sheet on the equatorward side. For $B_z>0$ and B_y small the ionospheric and field-aligned currents are localized near the dayside polar cusp, and the electric field has a dusk-down component in a narrow region near magnetic local noon in agreement with reported satellite measurements. The associated distribution of field-aligned currents consists of the region 1 current system and an additional pair of oppositely directed currents located poleward of the region 1 currents.
J. Geophys. Res., A, Paper 4A0758

5736 Magnetic Tail
SOURCES FOR ENERGETIC IONS AT THE PLASMASHEET BOUNDARY: TIME VARYING OR STEADY STATE?
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T. W. Speiser
Analyses of energetic ions observed at the plasmasheet boundary usually have assumed or inferred the existence of either a time varying or a steady state source. Because these assumptions are both important and conflicting, we have investigated the uniqueness with which they can be applied to the energetic ion observations. We have applied the results of assuming either a time varying or steady state source to analytic distribution function mappings and to a computer simulation of the ISEE-1 Medium Energy Particles Instrument (MEPI). The predicted MEPI ion signatures then are compared with observations. We find that in general it is not possible to determine the time varying or steady state nature of the source with single point observations of the ion distribution function. In specific instances, however, the time sequence of the ion distribution may allow such a determination. The likelihood of time variations in various parameters of the models (electric field, magnetic field, boundary velocity, etc.) plus the existence of complex boundary features (e.g. transverse and parallel waves), further complicate the issue making it very difficult for even multipoint observations to determine the time varying or steady state nature of the source. Nevertheless, independent of these assumptions, energetic particle events at the plasmasheet boundary analyzed to date show that the observations are consistent with single particle motion from a source several tens of earth radii down the tail which is characterized by an E^{-1} spectrum. Whether the source is time varying or steady state cannot be uniquely inferred from the data. (Particle observations, theoretical description, modelling).
J. Geophys. Res., A, Paper 4A8035

5739 Magnetopause
FLUID SIGNATURES OF ROTATIONAL DISCONTINUITIES AT THE EARTH'S MAGNETOPAUSE
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Fluid signatures in the MHD approximation at rotational discontinuities (RD) of finite width called rotational shear layers (RSL) are examined for general flow and magnetic geometries. Analytical and geometrical arguments illustrate that the fluid speed can either go up or down across an RSL for a fixed normal mass flux. The speed profile may or may not be monotonic with the phase of the magnetic rotation depending on the boundary conditions. The flow velocity may or may not be field aligned or "jetting" ($\hat{V}\cdot\hat{B} = 1$) as a result of traversing the RSL. In general, significant "convection" is expected in the layer. The observable signatures of (MHD) RSL's depend on 7 (boundary condition) parameters: (1) the mass density, (2-5): the incident normal and transverse components of the magnetic field and fluid velocity, (6): the angle ϵ between the incident tangential flow velocity and tangential magnetic field, and (7): the size of the magnetic angular rotation implemented by the layer $\Delta\phi$. This general survey illustrates the singular character of the Petschek geometry and that the model predictions of "jetting" and monotonic speed increases through the layer may not be used as general signatures of RSL's. This is especially true along the Levy, Petschek and Sisacoe outward magnetopause boundary where the fluid flow, $\Delta\phi$ and ϵ are generally all different from the Petschek regime. Accordingly, the lack of observed speed increases across the magnetopause can no longer be used by itself to infer that the magnetopause is locally closed. Of the spectrum of MHD RSL's that are possible the "accelerating" ones require special boundary conditions most generally occurring near the nose of the magnetopause; the "decelerating" RSL's become increasingly more probable at magnetopause crossings removed from the sub-solar point. Documented RSL's have been located within the spectrum of possible signatures; the number of RSL's reported to date implies only a lower bound for their frequency of occurrence since surveys conducted to date have excluded the "decelerating" ones. (Fluid Signatures, rotational discontinuities).
J. Geophys. Res., A, Paper 4A0700

5775 Trapped particles
THE CHARGE STATE COMPOSITION OF 0.4 MeV HELIUM IONS IN EARTH'S OUTER RADIATION BELTS DURING QUIET TIMES
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We present measurements of the charge state of 0.40-0.55 MeV helium ions in earth's outer magnetosphere (L 6) using a novel technique. The radial gradient of the helium ion flux and the east-west anisotropy in the pitch-angle distribution are both measured. These are combined with measurements of the magnetic field to calculate the flux-weighted average ion gyroradius. Since the magnitude of the magnetic field and the energies of the ions are known, the gyroradius determines the ion's charge state. During two pairs of geomagnetically quiet days in 1979 we find that most of these ions are singly charged. This result is in accord with theoretical calculations which find that charge exchange reactions between these ions and the neutral hydrogen geocorona are the dominant factor in controlling the charge state of these ions at times longer than a day after their injection. Our results also suggest that the mean charge state of these helium ions may vary with position in the magnetosphere and with time. (Energetic ions, charge state measurements, helium).
J. Geophys. Res., A, Paper 4A8011

5780 Wave propagation
A RECONCILIATION OF PROPAGATION MODES OF AURORAL KILOMETRIC RADIATION
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The propagation modes of AKR are theoretically investigated by three-dimensional ray tracing using an electron density model based on the auroral plasma cavity. Both R-X mode and L-O mode observations are explained in a consistent manner. The following assumptions are used for the ray tracing, which are based on observations near the source. 1) The radiation is generated in both R-X and L-O modes. 2) A range of ratios of the wave frequency to the R-X mode cutoff frequency f/f_x is from 1.01 to 1.1. 3) AKR waves are generated at wave normal angles almost perpendicular to the geomagnetic field. 4) AKR is generated in the auroral plasma cavity along a nightside field line with an invariant latitude of 70°. L-O mode waves can propagate within a wider region than R-X mode waves. Observed characteristics of AKR can be well explained under the following two additional assumptions, which are consistent with the cyclotron maser mechanism. 1) The R-X mode is stronger than the L-O mode. 2) Predominantly up-going waves are generated at the source. The R-X mode is dominant at high latitudes because it is stronger. The L-O mode is received in lower latitudes where the R-X mode waves cannot reach because of refraction and reflection mainly in the vicinity of the source and the plasmapause. Previous papers which claim the R-X mode radiation are reconsidered. The present interpretation consistently explain the results of their observations without contradiction with an existence of the L-O mode. It is clarified that they observed both modes. (Auroral kilometric radiation, ray tracing, propagation modes).
J. Geophys. Res., A, Paper 4A8030

5785 Particles and Fields - Magnetosphere (whistlers)
TEMPORAL EVOLUTION OF WHISTLER GROWTH IN A COLD PLASMA INJECTION EXPERIMENT
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Using a simple time dependent cold plasma density model and assuming a typical ambient radiation belt environment, we study the evolution of the whistler mode turbulence and particle precipitation in a cold plasma release experiment similar to one which may be conducted as part of the AMPTE program. It is known from earlier work that the release of cold lithium ions can significantly lower the critical energy E_c above which the resonant radiation belt electrons can pitch angle scatter. We study the time evolution of the one pass gain factor for a whistler wave packet and find that for parameters accessible to AMPTE type experiments the gain factor is large enough to ensure strong whistler turbulence and strong pitch angle diffusion of radiation belt particles with energies in the range between the ambient value of E_c and the reduced value of E_c. Estimates for the total power input to the ionospheric footprint of the release are of the order of an erg/cm²/sec. This precipitated energy should produce a patch of visible aurora. This effect should also persist for many hours. (whistler mode, temporal evolution, AMPTE, turbulence).
J. Geophys. Res., A, Paper 4A0698

Physical Properties of Rocks

6110 Elasticity, fracture and flow
THE EFFECT OF PRESSURE ON POROSITY AND THE TRANSPORT PROPERTIES OF ROCK
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We reanalyze the flow model proposed by Wyllie and Rose in which the complicated flow network through the pore phase of rock is replaced by a single representative conduit. Although the model is a very simple representation of the complicated pore phase in rock, we find that it provides an adequate simulation of how the transport properties vary with external pressure. Expressions derived for fluid permeability k and formation factor F are combined to give an expression for the mean hydraulic radius of the pore phase. Using this expression, we show that the exponent r in the empirical relationship, $k \propto F^{-r}$, must fall in the range $1 \le r \le 3$. Also, we use the expression for hydraulic radius to estimate the crack area per unit volume and standard deviation of the height of the asperities on the microcrack surfaces for two granites. The values are in reasonable agreement with other estimates.
J. Geophys. Res., B, Paper 4B0654

Planetology

6120 Equations of State
SHOCK-WAVE EQUATIONS OF STATE USING MIXED-PHASE REGIME DATA
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A method is described that uses Hugoniot data in the mixed-phase regime to further constrain equation of state (EOS) parameters of low- and high-pressure phases of materials undergoing phase transitions upon shock loading. We compute the relative proportions of low- and high-pressure phases present in the mixed-phase region and apply additional tests to the EOS parameters of the separate low- and high-pressure phases by invoking two simple requirements: the fraction of high-pressure phase must (i) increase with increasing shock pressure, and (ii) approach one at the high-pressure end of the mixed-phase regime. We apply our analysis to previously published data for potassium thioferrite, $KFeS_2$, and pyrrhotite, $Fe_{0.9}S$. We find that including the mixed-phase regime data in the $KFeS_2$ analysis requires no change in the published high-pressure EOS parameters. For $Fe_{0.9}S$, we must modify the high-pressure phase EOS parameters to satisfy both the mixed-phase and high-pressure phase Hugoniot data. Our values for zero-pressure density, bulk modulus and first pressure derivative of the bulk modulus of the high-pressure phase of $Fe_{0.9}S$ are 5.3 Mg/m³, 106 GPa, and 4.9, respectively.
J. Geophys. Res., B, Paper 4B0741

6180 Thermal Properties
RADIATIVE HEAT TRANSFER IN MOLTEN AND GLASSY OBSIDIAN
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We have measured optical transmittance spectra in rhyolitic obsidian samples in the wavelength range λ= 380-5500 nm and at temperatures T from 19°-1145°C, above and below the softening point. From the transmittance, we calculated the absorption coefficient $\alpha(\lambda,T)$ and the radiative thermal conductivity $K_R(T)$. K_R ranged from 3×10^{-3} cal cm^{-1}s^{-1}K^{-1} (1.2 W m^{-1}K^{-1}) at 700°C to 12×10^{-3} cal cm^{-1}s^{-1}K^{-1} (5 W m^{-1}K^{-1}) at 1145°C. The 700°C value is comparable with lattice thermal conductivity K_L of about 4×10^{-3} cal cm^{-1}s^{-1}K^{-1} (1.7 W m^{-1}K^{-1}). Removing scattering effects due to bubbles from the transmittance spectra by lowering the absorption base-line increased K_R to 20×10^{-3} cal cm^{-1}s^{-1}K^{-1} (8.4 W m^{-1}K^{-1}) at 1145°C. Because scattering by bubbles is likely to be small in confined magmas, these numbers are probably minimum values for K_R and indicate that in active plutons radiative heat transport could be greater than lattice conductivity by more than a factor of 2 at 1000°C. Thus, melting markedly strengthens K_R, and radiative heat transport is probably the dominant component of the total conductivity $K = K_L + K_R$ in silicic magmas. These relatively large values of K can be applied to models of the thermal evolution of magma bodies and to cooling of intrusives. (Thermal conductivity, radiative heat transfer, melt physics).
J. Geophys. Res., B, Paper 4B0601

Seismology

6905 Body Waves
FOCAL DEPTHS AND FAULT PLANE SOLUTIONS OF EARTHQUAKES AND ACTIVE TECTONICS OF THE HIMALAYA
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We have compared synthetic seismograms with long period body waves for nine earthquakes with epicenters in the Himalayan arc to determine depths of foci and to improve fault plane solutions. Focal depths are shallow (10-20 km). Inferred slip vectors are locally perpendicular to the mountain range; they plunge very gently (~10°) in the eastern sections of the range and more steeply (~25°) in western sections. Assuming India to be a rigid plate, the radially oriented slip vectors imply that southern Tibet extends at about half the rate of underthrusting in the Himalaya, and therefore probably at about 5-10 mm/yr. The shallow depths and gentle dips of the fault planes, at least for the events in the eastern half of the range, are consistent with coherent underthrusting of the Indian plate beneath, at least, the Lesser Himalaya. The steeper dips of fault planes in the western part of the arc might reflect deformation of the overriding thrust plate or simply a steepening of the main underthrusting zone beneath the Greater Himalaya.
J. Geophys. Res., B, Paper 4B0599

6970 Explosion seismology
A COMPARISON OF VELOCITY AND ATTENUATION BETWEEN THE NICOBAR AND BENGAL DEEP SEA FANS
R. S. Jacobson (College of Oceanography, Oregon State University), G. G. Shor, Jr. and Michel Bée
The compressional wave velocity and attenuation measurements from a deep source, deep receiver seismic refraction experiment from the Nicobar Fan, Indian Ocean, are presented and compared to a similar set of measurements at the Bengal Fan. The two deep sea fans consist of thick sections of turbidites derived from the same sediment source but have slightly different depositional histories. Travel time inversion of the data into a velocity depth model uses the tau-zeta linear inversion scheme. We present a revised reparameterization of the travel time data and improved error analysis for the inversion process. Although the velocity structures with depth are morphologically similar, there exist discrete differences between the two stations. In the Nicobar Fan, the initial velocity (assumed) is 1.513 km/s, with an initial gradient of 2.12 s^{-1}. The velocity increases smoothly with depth, while the velocity gradient decreases rapidly to a constant 0.81 s^{-1}. The Bengal Fan section showed the same trend, although the velocity gradient at depth was only 0.67 s^{-1}. The attenuation profiles are similar only in gross structure, with the Nicobar Fan values of Q^{-1} being a factor of 3 to 4 less than the Bengal station. The differences in velocity and attenuation structure can be attributed to a number of causes, including porosity and sedimentation rates (which are related to the distance from the sediment source) and the presence of a normal fault near the Nicobar Fan site. This fault may act as a conduit for water removal in the presence of overburden pressure. It is believed that porosity changes, due to whatever cause, dominate the lateral and vertical variations of velocity, velocity gradients, and (together with trended sediments) attenuation in thick sedimentary sections. (Sediments, velocity gradients, attenuation)
J. Geophys. Res., B, Paper 4B0433

6940 Phenomena Related to Earthquake Prediction
GEOPHYSICAL AND GEOLOGICAL EVIDENCE FOR FRACTURING, WATER CIRCULATION AND CHEMICAL ALTERATION IN GRANITIC ROCKS ADJACENT TO MAJOR STRIKE-SLIP FAULTS
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Gravity and seismic measurements collected on granitic plutons cut by the San Andreas, Garlock and San Jacinto faults of central and southern California show that these faults are bounded by belts of anomalous rock extending 2 to 5 kilometers on both sides of the surface traces of the faults. Borehole and petrographic studies show that anomalously low densities and seismic velocities in this zone are due to both fracturing and chemical alteration. Fracturing, water circulation and alteration are inexorably interrelated. High fracture densities are required to provide the permeability that allows water to reach and react with rocks hundreds to thousands of meters below the surface. Alteration products stable to seismogenic depths include montmorillonite (MO). Since the products of this alteration include expansive clays, this process is self-limiting. Formation of MO is facilitated by sparse water, whereas kaolinite and other clays can form if the amount of water exceeds the quantity needed for MO. Earthquakes periodically reopen the blocked fractures, a mechanism necessary in generating the broad, deep zone of pervasive alteration inferred from geophysical measurements. These geophysical and petrological patterns are clues not only to the evolution of these faults, but also to the dynamics of mechanisms currently operating within the seismogenic zone. This deep circulation model predicts that the strength of a fault segment varies in time. Timing of major earthquakes may be due as much to temporal strength variations as to stress events in the crust. Significant pre-seismic changes in the physical properties of the crust are probably confined to the zone of fractured rock immediately adjacent to the faults. (Earthquake prediction, fault gouge, fractures, granite).
J. Geophys. Res., B, Paper 4B0614

6970
S - P WAVE TRAVEL TIME RESIDUALS AND LATERAL INHOMOGENEITY IN THE MANTLE BENEATH TIBET AND THE HIMALAYA
P. Molnar (Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139) and W.-P. Chen
The average S wave travel time residuals from 11 earthquakes each in Tibet and the Himalaya imply that there are marked lateral variations in structure beneath Tibet and the Himalaya. Average S - P wave residuals, measured with respect to the J-B tables, for each of 11 earthquakes in the Himalaya are less than +1 s. Average J-B S - P residuals from 10 of 11 earthquakes in Tibet, however, are greater than +1 s, even when corrected for the large crustal thickness of Tibet. The largest values, 2.5s, 3.1s, 3.4s, 4.5s, and 4.9s, are for five events in central and northern Tibet, and they imply that the average velocities in the crust and upper mantle of these portions of Tibet are 4-10% lower than those beneath the Himalaya. Therefore, it is unlikely that a shield structure underlies these parts of Tibet, unless these S - P residuals are due to variations in structure deeper than 250 km. S - P residuals from 7 other events each in western and eastern Tibet are 1 to 2 s late, and hence suggest that velocities beneath these areas are also somewhat lower than beneath shields. The mean S wave velocity seems not only to be different beneath Tibet and the Himalaya but also seems to increase from a minimum beneath northern Tibet to values close to those of the average earth toward the east, south and west. (S - P Residuals, mantle, Tibet, Himalaya).
J. Geophys. Res., B, Paper 4B0684

6970 Upper Mantle Structure
MAPPING THE UPPER MANTLE: THREE DIMENSIONAL MODELLING OF EARTH STRUCTURE BY INVERSION OF SEISMIC WAVEFORMS
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A method is presented for the inversion of waveform data for the three dimensional distribution of seismic wave velocities. The method is applied to data from the global digital networks (International Deployment of Accelerometers, Global Digital Seismograph Network); the selected data set consists of some 2000 seismograms corresponding to 53 events and 870 paths. The moment tensors of the earthquakes are determined through an iterative procedure which minimizes the corrupting influence of lateral heterogeneity. A global model is constructed for shear wave velocity, expanded up to